Greater Moncton Sewerage Commission
Commission d'épuration des eaux usées du Grand Moncton

UN-HABITAT

GLOBAL ATLAS OF EXCRETA, WASTEWATER SLUDGE, AND BIOSOLIDS MANAGEMENT: MOVING FORWARD THE SUSTAINABLE AND WELCOME USES OF A GLOBAL RESOURCE

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Contents

Tables and Figures

Overview

Australia

Austria

Brazil

Bulgaria

Burkina Faso

Cameroon

Canada

Greater Moncton Sewerage Commission (GMSC)

Ontario

Québec

Western Canada

European Union

Finland

Germany

Hungary

Italy

Japan

Japan: General

Outline of wastewater treatment in Kobe

Jordan

Mexico

Mozambique

New Zealand

Norway

Portugal

Russia

Slovakia

Slovenia

South Africa

Faecal sludge management

Turkey

USA

Summary of wastewater treatment solids management in the United States

Delaware – Kent County Regional Wastewater Treatment Facility (KCRWTF)

Illinois – Metropolitan Water Reclamation District of Greater Chicago

Foreword

Distasteful though the subject may be to some, the treatment of human waste – or its lack of treatment – poses an important problem facing the world's populations, particularly in developing countries and particularly in cities.

As everyone knows, sewage containing human excrement, as well as wastewaters and other sorts of wastes, poses a serious health threat unless treated properly. Unfortunately, in much of the world such proper treatment is absent or rare.

In this atlas, a variety of countries and regions in the world report on sanitation in their respective jurisdictions. They range from developing countries with substantial portions of the population without access to modern plumbing or sanitation, to developed countries with sophisticated treatment plants linked to elaborate sewerage systems. They range from countries trying to deal with outmoded sanitation systems to others that have been able to invest in the most modern technology and equipment.

The following chapters deal with issues spanning the spectrum from whether a jurisdiction has enough toilets to issues over the conversion of sludge into useful soil enrichment material.

Even beyond the question of how to remove human waste from homes and workplaces, there are issues revolving around what to do with it, including issues related to treatment and conversion to useful products, such as fertilizers or building materials. These second-level questions sometimes raise their own problems, including safety and popular acceptance of some of the solutions available.

Sanitation is a particularly important matter because people who live in remote villages, wealthy suburbs, urban slums and glittering cities share a need to avoid exposure to the disease, vermin and other hazards entailed with proximity to dealing with sewage. We share a planet with finite space and resources, and a common interest in turning this unavoidable product of our existence into something useful that can be recycled instead of just dumped into our backyards, rivers or oceans.

This atlas represents the first effort to catalogue this problem on a worldwide scale. It is a problem that will not go away unless serious efforts are made to tackle it.

These efforts will have to be made cooperatively by people, countries and institutions around the world. It is my hope that this atlas will be an important step in informing these efforts.

Anna Tibaijuka
Executive Director, UN-HABITAT

Before and after – Land application on farm. Photo © GMSC

Acknowledgements

In 1996, the International Association on Water Quality published a "*Global Atlas of Wastewater Sludge and Biosolids Use and Disposal*", edited by Peter Matthews.

During the International Water Association (IWA) Biosolids Specialists Conference in Moncton, New Brunswick, Canada in June 2007, it was decided to publish a current issue of the Global Atlas with the launch scheduled at the IWA – World Water Congress and Exhibition in Vienna, Austria during 2008, the International Year of Sanitation.

The preparation of this Atlas is the result of the dedicated efforts of a wide range of stakeholders from all regions of the globe. Their knowledge and expertise has been essential to the successful publication of this Atlas.

The "*Global Atlas of Excreta, Wastewater Sludge, and Biosolids Management: Moving Forward the Sustainable and Welcome Uses of a Global Resource*" was prepared under the leadership of the Greater Moncton Sewerage Commission; the guidance of the Editors: Ronald J. LeBlanc and Roland P. Richard (Greater Moncton Sewerage Commission), Peter Matthews (UK Sustainable Organic Resources Partnership), and the financial support of the UN-HABITAT.

Appreciation and special thanks are extended to the Editors and authors of the Introduction Chapter: Ronald J. LeBlanc, Peter Matthews and Roland P. Richard; Ned Beecher (North East Biosolids and Residuals Association) author of the Overview Chapter; Graham Alabaster and Julie Perkins for the UN-HABITAT coordination.

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Sheep graze on grass grown on biosolids soil on top of a closed municipal solid waste landfill in New Hampshire, USA. Photo courtesy of Resource Management, Inc. ©

Introduction

Authors: Ronald J. LeBlanc, Peter Matthews, Roland P. Richard

Introduction

It is crystal clear that, in addition to clean air, the well-being of our planet also requires that water, wastewater and the resulting biosolids (sludge) need to be managed more seriously, and in a focused, coordinated and cooperative manner.

The idea for the creation of this *Global Atlas of Excreta, Wastewater Sludge, and Biosolids Management* originated at the IWA Biosolids Conference, *"Moving Forward Wastewater Biosolids Sustainability: Technical, Managerial, and Public Synergy"* held in Moncton, New Brunswick, Canada in June 2007. At this conference representatives of the International Water Association (IWA), Water Environmental Federation (WEF) and European Water Association (EWA) agreed that it would be very useful to produce a current edition of the "Global Atlas of Wastewater Sludge and Biosolids Use and Disposal" which had been published in 1996, with Peter Matthews being the original editor.

In recognition of the International Year of Sanitation, UN-HABITAT collaborated with the Greater Moncton Sewerage Commission, hosts and organizers of the Moncton conference, to publish this Atlas, which comprises the inputs from cities and organizations around the world. The objective of this Atlas is to provide a global picture of the current status of information and opportunities for wastewater biosolids/sludge disposal and reuse, including trends and regional comparisons since the last publication. The Atlas also aims to contextualize biosolids management within the larger framework of global development challenges.

BACKGROUND AND HISTORICAL REVIEW OF THE CREATION AND MANAGEMENT OF WASTEWATER SLUDGE AND BIOSOLIDS

Wastewater treatment and the management of the solids it produces are global issues, with growing challenges, that must address the concerns of all of the stakeholders, including the facility administrators and operators, the regulators, the politicians, the scientific community, the wastewater generators, the taxpayers and the general public.

Conventional centralized sewerage systems require an elaborate infrastructure to transport large amounts of wastewater. While this approach may work well in some circumstances it is impractical in many other locations. In industrialized countries, one approach has been to use mechanical and biological processes (primary and secondary and in some cases tertiary) to remove suspended solids, bio-chemical oxygen demanding substances (BOD) and other pollutants. The wastewater treatment ranges from simple collection systems with discharges of untreated but screened effluents directly to receiving bodies of water to sophisticated tertiary level treatment plants. The products of the treatment processes are primarily clean effluent and solids in the form of a sludge. The higher the level of treatment achieved, the higher are the volumes of wastewater solids being created.

For countries with very little or no access to basic sanitation, increasing the effectiveness of management of excreta at the household level may have the biggest health implications and it may be the biggest challenge. While throughout the world there is significant and growing investment in sanitation, almost 41 percent worldwide (± 2.6 billion people) live without proper sanitation facilities.

The end solution for wastewater sludge and disposal varies greatly on where in the world it is created. The sludge ("solids") may be disposed to landfill, used as a source of energy, treated and used on land as a fertilizer and soil conditioner, or may even be used as a raw material to extract valuable contents. When sludge is properly treated, of good quality and used on land, it is now known widely as 'biosolids' to distinguish it in public acceptance terms from other sludge. But despite the known benefits of recycling biosolids, it is not a universal practice. This is a paradox, because many societies have, and still do, use human faeces directly as a fertilizer.

In a global context of rising concern over disease, climate change, environmental pollution and resource scarcity, there is a compelling need to embrace the beneficial uses of wastewater solids as biosolids and not consider the by-products as a "waste".

The construction of a wastewater treatment system is the easy part, and only the start, when dealing with wastewater. Operating wastewater treatment systems, and the management of the solids, created by the treatment processes, is where the challenges and the real work begin. As a consequence, planning with regard to biosolids recycling or disposal options must be undertaken long before a wastewater treatment plant is operational.

PUBLIC ACCEPTANCE

Whilst wastewater solids contain valuable organic matter and nutrients, which are very beneficial to enrich soil, they must be protected from contamination and treated to avoid risks and used safely in accordance with good practice. The failure to take into consideration fully the concerns of all of the stakeholders, including the concerns of the general public, has resulted in predictable but preventable problems including the banning of scientifically acceptable biosolids recycling options in different countries.

For many stakeholders, newly constructed wastewater treatment facilities can present a paradox. On one hand there is an insistent message that untreated wastewater causes pollution, environmental damage and risk to public health. On the other hand, utility operators have to dispose of the wastewater solids back into the environment. Public acceptance of such disposal is therefore a major factor. Practical experience has shown that in the mind of some people, full treatment or clean-up programmes for wastewater means making the problem disappear. It is hard for them to understand why the most extensive clean-up programmes produce the most solids. Hence development of wastewater treatment still has, as one of its objectives, the minimization of solids production. Fast compact sewage treatment processes may produce bulky solids and there is a need to deal with these. Consequently there is also an emphasis on improvement in solids thickening, dewatering and disposal methods.

On the issue of public acceptance there has been an evolving view that beneficial uses should be made of biosolids, as opposed to simply disposing of them in landfills. This is consistent with an overall view that in terms of global environment protection every effort should be made to use all waste in preference to unproductive disposal. Indeed, there has been evolution in philosophy on these matters from pollution control to pollution prevention, to environmental management to resource recovery.

However, such visionary political or even personal aspirations meet practical obstacles when it comes to wastewater sludge. There is emotional confusion. Many are told that anything to do with faeces is potentially hazardous – for every good reasons of public health. We are told to wash our hands after going to the toilet, to use proper sanitary facilities, to avoid soiled clothing and so on. This creates a faecal aversion barrier which results in a variety of reactions ranging from ribald humour to disgust.

There is no connection, for most people in societies served by centralized sewerage facilities, between the use of a toilet and what happens to the wastes that they flush. So it should not be surprising that when the utility manager and local farmer announce a programme of agricultural use for biosolids that there may be local reaction of NIMBY, (Not in by back yard). Political, academic and journalistic reputations can feed off these legitimate concerns; so it is no wonder that stakeholders may be confused and concerned. "Likewise, if there is any

Dredge for Lagoon Desludging, South East Australia. Photo © Allen J Gale public debate on the use of biosolids there are some who advise, in the name or fear of safety, to do doing nothing at all with biosolids. Consequently in anticipation of public debates the language used for discussion is critical – "properly treated biosolids used in agriculture sends a very different message than 'sewage sludge dumped on land'!"

As global sanitation programmes extend, the challenge of using biosolids will increase. Each generation must improve on the works of the former generation. There is no "One Big Fix". Wastewater plant managers will always have to be vigilant in working with stakeholders.

Consequently, a successful and sustainable wastewater treatment and biosolids recycling management plan requires a Big Picture view and a sustainable approach, which take into consideration the concerns of all stakeholders. The stakeholders want the use of biosolids, and indeed of all methods of wastewater solids management, to be "safe, sustainable, and welcomed".

The collection of foul waste water from larger communities has a history of thousands of years but as villages and cities grew, wastewaters were eventually channeled directly, for the most part, into rivers or other water bodies. Small communities with sewer systems retained the familiarity with the use of 'night' soil. In the poorest regions of the world wastewater drainage was sometimes done by way of open trenches. In the wealthiest regions of the world, domestic sewage or wastewater was essentially hidden, as these regions had the funds to build underground collector systems that transported their wastewater directly to rivers, lakes, bays and oceans.

As a consequence, in the wealthiest regions of the world, environmental concerns regarding domestic sewage and wastewater were hidden and not visible to the general public. The public did not pay for the treatment functions, as treatment was expected to be provided by the receiving water streams. Unfortunately, there was little understanding of the impact on the receiving waters.

Eventually science, common sense, environmental and health concerns resulted in conclusions and legislation that made it no longer acceptable to dispose of wastewater directly into the receiving environment without treatment. As a consequence, the public is now required to pay for the wastewater treatment functions.

The production of sludge is a natural and unavoidable consequence of wastewater treatment functions and in many places it was used much in the way of using night soil. But there was, for a long time, a failure to take a sustainable long term "Big Picture" view of how to do this in an acceptable way. During the last fifty years, once more, science has provided many answers on the management of risks, but much more needs to be done on public acceptance.

It is crystal clear that properly treated biosolids have beneficial uses and should be treated as a product rather than a waste. However the acceptance of sustainable beneficial uses of biosolids requires the creation and retention of an atmosphere of trust and confidence with the general public. This trust is an essential ingredient of the wastewater industry's ability to achieve success.

Consequently, a successful and sustainable wastewater treatment and biosolids recycling management plan requires a Global Big Picture view and a sustainable approach, which take into consideration the concerns of all stakeholders. A necessary ingredient required to develop and implement such a management plan involves consultation, co-operation and coordination between the operators, the general public, the regulators, the politicians, the scientific community and the wastewater generators.

A necessary component of this trust is a proper wastewater treatment and biosolids management program that is transparent and that involves, on a global level, all stakeholders in the wastewater industry. In short, the aim is to have a shared understanding that it is "safe, sustainable, trusted and welcomed" – but there is a long way to go before this becomes a global reality.

The is a need to recognize that many people in developing communities, or communities in transition do not yet have the benefits of sewerage and wastewater treatment. They are confronted with the daily challenges of disposing and using human faeces or 'night soil' directly. They need support in ensuring that such practices are not a threat to community health and, in recognition of that, it was decided that these issues would be added to this Atlas.

THE GLOBAL BIG PICTURE

It is often said that the world is getting to be a smaller place. People are traveling and migrating more than at any time in history. Global companies, trade and governance are day to day realities. Consequently people expect the same high standards of the quality of life where-ever they live, visit or work. Consequently, there is convergence of aspiration. Increasingly "Global Big Pictures" are needed in which information and experiences are shared.

This Atlas provides a global summary with the intent that it be used as a resource of information of current wastewater treatment, disposal and reuse practices which will hopefully enable identification of current trends, solutions and alternatives that could serve to promote action towards improving wastewater solids management and the beneficial use of biosolids around the world.

In addition to being a source of valuable nutrients that enable barren soils to become productive, and to being a source of energy, wastewater sludge and biosolids can be used for a variety of other beneficial uses. By way of example, at the forefront of discussions today are the impacts of climate change and air quality. Beneficial uses of biosolids hold great potential to reduce Green House Gas (GHG) emissions and sequester atmospheric carbon.

OBJECTIVES OF THE ATLAS

The objectives, for this Atlas as established at the 2007 Moncton conference are as follows:

1. Update the information contained in the first and only edition (1996) and increase the number of countries and agencies included.
2. Help bring a "Big Picture" approach to environmental stewardship and help with the continuous development of standards and best practices for the management and beneficial use of wastewater sludge, faecal waste and biosolids on a global level.

3. Provide comparisons of how a "benchmark wastewater sludge" would typically be regulated and managed in different nations or regions within a nation.
4. Provide information on the regulation of faecal waste, wastewater sludge, and biosolids in nations, and regions within nations, throughout the world including in developing countries and countries in transition without centralized treatment.
5. Publish the "Current Edition" by August 2008 with the official presentation at the IWA – World Water Congress and Exhibition in Vienna – 2008.

It was agreed that the same format as the initial 1996 version should be used, but modified to reflect experiences of the past twelve years and contemporary needs and interests, including the addition of the disposal of faecal matter. The central idea remains the same as in the first Atlas; it is to take a typical urban sludge from a well regulated system and then to apply disposal and utilization rules to see what the effects would be under different circumstances. This enables comparisons to be made from region to region around the world and with the initial entries to the first Atlas. The same benchmark sludge and soil parameters were used. A modified response was requested from developing countries with cities where centralized treatment facilities do not exist.

Although many contributions followed the benchmark concept, others did, or could, not. However, each contribution provides a level of information of very high quality and has enabled very useful comparisons and more importantly has provided a summary of the current situations.

SUMMARY

It is the aim of this Atlas to provide and transfer knowledge and benchmark information to others in order to assist in the creation of proper sustainable wastewater treatment and biosolids management programs across our planet.

It is our hope that this Atlas will help to bring a 'Big Picture' approach to environmental stewardship and will aid with the continuing development of standards and best practices for the management and beneficial use of sludge and biosolids on a global level.

A concise overview of the relevance of biosolids management today, the key global trends with temporal and regional comparisons, including recommendations for advancing the global biosolids agenda is presented in the next chapter.

The information provided in soliciting the contributions is attached as Appendix A and Appendix B.

Ronald J. LeBlanc *Chairman, Greater Moncton Sewerage Commission, Canada*
Peter Matthews *Chair, Sustainable Organic Resources Partnership, United Kingdom*
Roland P. Richard *Special Projects Manager, Greater Moncton Sewerage Commission, Canada*

Editors August 2008

Appendix A – Description of contribution

Section A – Introduction

At the International Water association (IWA) Biosolids Conference in Moncton, Canada in June 2007, representatives of the IWA, WEF and the European Water Association (EWA) agreed that it would be very useful to produce a second edition of the Atlas, first produced in 1996 and published by IWA. It was agreed that the same format should be used, but modified to reflect experiences of the past ten years and contemporary needs and interests, including the addition of the disposal of faecal matter.

The central idea remains the same; it is to take a typical urban biosolids/sludge from a well-regulated system and then to apply disposal and utilization rules to this to see what the effects would be under different circumstances. This enables comparisons to be made from region to region and of course with previous entries. The same benchmark biosolids/sludge and soil will be used. It is recognized that returning the full answers to the questionnaire will be onerous and if this is not possible, an actual operation approximating to the central model should be reported. We will aim to have one contribution per set of rules and these could be a regional or national level.

Section B – The benchmark sludge/biosolids

The raw benchmark biosolids/sludge is defined as follows:

- Population equivalent (domestic and some mixed industry). The original population equivalent was 100,000. Report the population equivalent you are reporting.

Raw sludge thickened, on dry solids	
Dry Solids	6%w/w
Organic Matter	75%w/w
Zinc	1000mg/kg
Copper	500mg/kg
Nickel	40mg/kg
Mercury	3mg/kg
Cadmium	3mg/kg
Lead	200mg/kg
Total Nitrogen	3.5%w/w
P205	3.5%w/w
K2O	0.2%w/w

The purpose is to compare typical disposal operations.

If you cannot make the submissions on the basis of the details and assumptions given, your contributions will still be very welcome, but please explain why you are different. An example might be that your rules restrict biosolids use to concentrations lower than those defined in the assumptions.

We are maintaining the assumption not to define a benchmark soil as local soil conditions can be a major influence on the practicalities of operations. However, if any operation assumes or requires soil background values and these are not readily available, the following values may be used as a reference.

Zinc	40mg/kg
Copper	10mg/kg
Nickel	15mg/kg
Mercury	0.05mg/kg
Cadmium	0.1mg/kg
Lead	20mg/kg
pH	6.5

The analytical assumptions center on a core of determinations which are likely to be common to many situations. The concentrations have been set so that there is not likely to be any unique problems. The exercise has been set up to deal with typical circumstances, not special ones. However, it is known that local rules may contain other numerical requirements for sludges and soils. If this is so for your case, please could you add assumptions for those requirements. These assumptions are for your typical sludge/biosolids and soils. A brief explanation of these unique differences would be helpful. If a typical biosolids/sludge in your area is of worse quality than those used in the model, if possible, please stay with the values provided, but you may like to provide a brief note on the disparity. However, you might like to alter the pH value of the soil to reflect your regional circumstances more accurately, but please explain this point.

In exceptional circumstances that typical biosolids/sludges in your region are much worse than the model and your operational practices and regulations reflect this, then we recognize that adhering to the model may be difficult. So under these circumstances, please use assumptions based on model sludge with ten times the values given. Please make it absolutely clear what the basis of your return is. Please remember that this is not an exercise in the disposal of an individual sludge but a comparison of practices and regulations for regions. We have not allowed for a typical sludge better than that given earlier so please follow the approach outlined above.

Section C – Comparisons of practices

The ideal outcome is to take the benchmarks and to subject them to disposal and utilization practices to give an insight as to the effect of local regulations and policies. If you have freedom of choice of use/disposal options – usually agricultural use, or other uses, or landfill, or incineration, please describe how you would choose the option for disposal and what the practical and economic constraints which affect your choice. Identify the most usual methods of use/

disposal. The greater attention in your contribution should be on the options you would actually use. Regional and national statistics would be useful.

Economics are very much a feature of operations, but comparisons can be difficult because of the influence of external factors, for example international exchange rates and the local cost of commodities such as fuel and power. This project is a comparison of practical operations not of the economic structures of costs. Nevertheless, there is interest in comparative costs and hence we have used commodities as a benchmark which are not only of international relevance but also contribute to sludge disposal costs. Please give the following in your local currency:

- Proportion of annual cost (operational and finance charges) of sewage treatment and disposal attributable to sludge treatment and disposal for a typical works of 100,000 p.e.
- Charge to customers for treating one cubic metre of sewage
- Cost of 1000 litres of diesel fuel
- Cost of one kilowatt hour of electricity

If mechanical dewatering is required typically to facilitate a successful operation, please describe briefly why this is so and the techniques employed.

Equally, please describe any stabilization and or disinfection techniques used to render raw sludge suitable for use and disposal.

Rules and regulations should be summarized as succinctly as possible for each option and in the most detail for the preferred option – whilst remembering that the Atlas has a primary focus on the use of biosolids. If possible, describe how risk assessment underpinned these and describe how this is used in day-to-day application of them. Please identify any 'hot issues' which could ultimately lead to a modification of the rules and regulations. If changes are planned or are imminent, please summarize the changes with planned dates.

In each case, the object is to identify the principal features such as the duration of operations – all factors being constant and equal – in the case of biosolids use this would be described as site-life. We are interested in a summary of the ongoing practical constraints which affect operations.

We are interested in how operations would be conducted. The fullest description would be given on the most likely operations. For those operations which are less likely, please give a brief description. If any option is prohibited, just say and describe no more. If an option is impracticable or of no consequence or these is no experience, please make a statement to those effects.

Section D – Template for return

Please provide the following for the benchmark sludge or the current local activity.

- Strategic selection of use/disposal practice – what would you probably do with it and any biosolids derived from it.
- Economic information.
- How would you conduct landfill, including the use of sacrificial land?

- How would you conduct incineration including nitrification? Specify whether it would be incinerated with other wastes.
- How would you manage use on arable land? Please assume typical staple crops – examples are maize (corn), wheat, oats, barley, sugar beet, soya beans, forage crops, industrial crops. If the land is in regions growing fruit and vegetables crops or other crops consumed raw by humans (such as nuts), please explain.
- How would you conduct conversion wholly or in part into a product to be used in the domestic or horticultural market e.g. lawns, parks and playing fields?
- How would you conduct use in forests/woodland, on conservation and non-sporting recreation land, for land reclamation?
- How would you conduct production of by products e.g. vitrified glass products, construction materials, fuel pellets, oil, protein, etc.

Now for the additional section. If your region has the practice of disposing of faecal waste from facilities not connected to mains drainage, please describe the controls and operational practices, however informal. Describe particular operation defining the population served.

Section E – Instructions for preparation of contributions

- File format: the format for electronic submission is Microsoft Word.
- Preparation of the Typescript:

  Left hand margin 3 cms, right hand margin 2.5 cms, bottom margin 4 cms. Typeface 12 pitch font times new roman 11/2 spacing. Paragraphs and main heading should be unnumbered. Main headings should be in capitals, subsections underlined and sub, subsections not underlined.

Section F – Submission of contributions

Please give the name, address, email address for the authors to be contacted and to be included in the Atlas.

Please submit to Roland Richard, at his e-mail rrichard@gmsc.nb.ca and notify Peter Matthews and Ronald J. LeBlanc of the submission, by no later than February 2008.

Project Managers

Peter Matthews	Chair UK Sustainable Organic Resources Partnership UK phone UK 1480 469270 pmatthews@pelicanport.freeserve.co.uk
Ronald J. LeBlanc	Chairman, Greater Moncton Sewerage Commission Canada Telephone: + 506-387-7977 ron.leblanc@gmsc.nb.ca

Appendix B – Description of contribution

OPTIONAL SHORTER VERSION FOR LOCALITIES WITHOUT CENTRALIZED SEWAGE TREATMENT

At the IWA Biosolids Conference in Moncton, Canada in June 2007, representatives of the IWA, WEF, and EWA agreed that it would be very useful to produce a second edition of the Atlas that was first produced in 1996 and published by IWA. It was agreed that the same format should be used, but modified to reflect experiences of the past ten years and contemporary needs and interests, including the addition of the disposal of faecal matter. It is with great pleasure that we are able to announce that this edition will be supported by the United Nations, which will publish the Atlas. The aim is to publish by August 2008.

NOTE: This version of the instructions is for use in those countries, regions, or localities that have little or no centralized or mechanized sewage treatment.

Please give the following information regarding the sludge/faecal sludge/septic waste/excrement produced in your country or region within a country:

- How much of these materials are managed in your jurisdiction each year? How much additional material is not managed, is ignored, and is untreated and/or untracked? Please describe the population(s) served by the management of these materials.
- Strategic selection of disposal practice – What is most commonly done with sludge/faecal sludge/septic waste/excrement in your country or region? Does it go to lagoons? Is it put in landfills or incinerated? Is it composted or treated in any way to make it usable on soils? What options are used? Please discuss in order from most common method to least common method.
- How are the decisions made as to what to do with it? Is risk assessment involved? Are decisions driven by cost, practicality, availability of equipment or labor – what drives decisions? Who makes the decisions?
- Economics are very much a feature of operations, but comparisons can be difficult because of the influence of external factors, for example international exchange rates and the local cost of commodities such as fuel and power. This project is a comparison of practical operations, not of the economic structures of costs. Nevertheless, there is interest in comparative costs and hence we have used commodities as a benchmark which are not

only of international relevance, but also contribute to sludge disposal costs. Please give the following in your local currency:

- What does it cost to dispose or use sludge/faecal sludge/septic waste/excrement?
- Charge to customers for treating one cubic metre of sewage
- Cost of 1000 litres of diesel fuel
- Cost of one kilowatt hour of electricity
- Please describe the processes of treatment, use, and/or disposal for the most common ways of use or disposal identified above.
- If it is used in agriculture, please describe how it is managed. Are there requirements regarding the soils receiving the material? What other requirements are there?
- If it is used on food crops or on lawns, parks, or playing fields, please describe how it is managed. What measures are taken to prevent contamination or disease transmission? Are there requirements regarding the soils receiving the material? What other requirements are there?
- If it is used for land reclamation or in forestry, please describe how it is managed.
- If it is placed in landfills, please describe how it is managed.
- Laws and regulations should be summarized as succinctly as possible for each management option discussed above and in the most detail for the preferred option. Does risk assessment underpin these laws and/or regulations? If so, please discuss.
- If mechanical dewatering is required typically to facilitate a successful operation, please describe briefly why this is so and the techniques employed.
- Equally, please describe any stabilization and or disinfection techniques used to render raw sludge, faecal matter, etc. suitable for use or disposal.
- Please identify any 'hot issues' that could ultimately lead to a modification of the rules and regulations. If changes are planned or are imminent please summarize the changes with planned dates.

Please remember that this is not an exercise in the disposal of an individual sludge/faecal sludge/septic waste/excrement, but a comparison of practices and regulations for different regions. Identify the most usual methods of disposal. The greatest attention should be on the options you – or others in your region – actually use. Regional and national statistics are also useful – anything that provides insight into the common practices for use and disposal of these materials; the economics of their management; and the effects of laws, regulations, and policies.

Instructions for preparation of contributions

See Appendix A: Section E – Instructions for preparation of contributions

Submission of contributions

See Appendix A: Section F – Submission of contributions

Secondary wastewater treatment tanks sit on top of primary treatment tanks at the Deer Island Wastewater Treatment Facility in Boston, Massachusetts, USA. The wastewater sludge from this facility is used to produce 75 dry tons of pelletized biosolids fertilizer each day. Photo © Ned Beecher

Overview

Moving forward the sustainable and welcome uses of a global resource

Author: Ned Beecher

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– Ned Beecher, Tamworth, NH, USA, June, 2008

DEFINITIONS

biosolids refers to the solid organic matter recovered from a sewage treatment process and used especially as fertilizer; in this chapter, biosolids includes excreta, faecal matter, and septage that has been treated and tested and is appropriate for use as fertilizer and/or soil amendment

eco-san (ecological sanitation) refers to an alternative approach to managing excreta in ways that minimize impacts the environment; eco san systems usually use little or not water and often separate urine and feces for separate treatment with the goal of using both as fertilizers and soil amendments

excreta refers to waste from humans, including urine and feces (fecal matter)

fecal sludge (faecal sludge) is the material collected from on-site sanitation systems such as latrines, non-sewered public toilets, and septic tanks; it is mostly composed of fecal matter (feces).

graywater refers to water that has been used to convey household wastes from baths, showers, and sinks – but not toilets; graywater contains minimal amounts of human excreta

heavy metals are basic elements (e.g. Cd, Cu, Hg Pb, Zn,) that, if exposure occurs to a large enough concentration of them, are known to be toxic to humans, plants, and/or animals; "heavy metals" is the commonly used term, despite the fact that some of the elements included are not metals at all (e.g. As, Se); all natural soils, animal manures, wastewater, excreta, wastewater sludge, and biosolids contain at least trace amounts of these and many other elements

latrine refers to a structure built for humans to defecate in

lagoon refers to a pond of wastewater or septage in which solids settle to the bottom and some treatment is achieved

pathogens are micro-organisms that can cause disease in humans; these include, for examples, bacteria (*Salmonella, Shigella, Campylobacter,* some strains of *E. coli,* etc.), Helminth worms (*Ascaris*, *Taenia*, *Trichuris trichuria*, etc.), enteric viruses (Hepatitis, Norwalk, Rotaviruses, etc.), and protozoa (*Cryptosporidium, Entamoeba*, *Giardia*, etc.).

peri-urban refers to development immediately adjacent to an urban area, between the suburbs and rural areas

preliminary treatment refers to the removal of coarse waste materials, such as rocks, sand, sticks, rags, and metal, from the wastewater stream by using bar screens, racks, and grit removal systems.

primary treatment refers to the treatment of wastewater by the gravity-driven settling of solids and flotation of scum

secondary treatment refers to the treatment of wastewater to remove dissolved solids (e.g. sugars) from the wastewater; this is done using micro-organisms to consume the wastes in aerated tanks, followed by settling of the micro-organisms and associated solids in a clarifier (a quiet settling tank) or pond

sewage is used synonymously with "wastewater"

septage refers to the solids removed from a septic tank that is part of a septic system

septic system refers to a local, on-site form of treatment for wastewater from one or several homes and businesses; a septic system collects wastewater solids (septage) in a tank and releases liquid waste from the top of the tank into the surrounding soil, often through a leach field

tertiary treatment (advanced treatment) refers to additional wastewater treatment processes that occur in addition to secondary treatment and are undertaken with the goal of creating cleaned water suitable for a particular purpose; common tertiary treatments include additional removal of nutrients (nitrogen, phosphorus), chemical treatments, pressure filtration, and polishing through, for example, a wetlands system

vector attraction reduction refers to treatment processes that stabilize and reduce the odors and other aspects of excreta or sewage sludge that attract flies, rodents, and other potential disseminators of pathogens

wastewater refers to water containing human excreta and household and business wastes

wastewater sludge (sewage sludge) is the term for the solids removed from wastewater at a wastewater treatment facility

wastewater treatment facility (sewage treatment plant, treatment works) refers to a facility that removes solids and other pollutants from water that has been used to clean and convey human and other wastes; most wastewater treatment facilities are comprised of a series of ponds or tanks in which the wastewater is kept still to allow for settling of solids interspersed with ponds or tanks where air is mixed in to promote the growth of micro-organisms that consume pollutants

NOTES ON LANGUAGE AND NUMBERS

- In this overview chapter, the following format is used to make references to the chapters that follow: "as the report from Brazil (Andreoli et al.) notes…" In this reference, the report from Brazil can be found in a subsequent chapter, and the authors of that report are Andreoli et al.
- The language in this overview chapter is American English. The English varies in the later individual chapters from each city, state/province, and country.
- This overview chapter uses metric units, commas between the thousand and million places, and decimal points for fractions: e.g. 6,543.21. Some of the later individual chapters use different units (e.g. USA pounds and tons) and number formats (e.g. 6.543,21).

- Throughout this *Atlas*, amounts of wastewater sludge and biosolids are commonly described in either wet weight (which includes the significant proportion that is water) or – more commonly – dry weight. Dry weight, or "dry solids," refers to the weight of just the solids, without the water. Using dry weight allows for accurate comparisons between wastewater sludges and biosolids that have different amounts of water in them.
- "Tonne" is used to refer to a mega-gram (Mg). "Ton" refers to the measure used in the USA. They are roughly equivalent – a tonne is equal to 1.1 ton.
- This overview chapter uses local currencies (with the equivalent in USA dollars appearing in parentheses).
- All data presented in tables and graphics are derived from the reports provided for this *Atlas* or the preceding, 1996 edition.

THE QUALITY OF THE PRESENTED DATA

The editors of this *Atlas* requested information and data from cities, states, provinces, and countries around the world. A general format and particular information were requested (see Appendix A and B for the instructions given to authors). However, programs that manage excreta, wastewater, wastewater sludge, and biosolids collect and organize information in different ways, which made it difficult for authors to reply to the editors' requests for information in a uniform way. Thus, each of the reports appearing in the later chapters in this *Atlas* provides somewhat different kinds of information in differing formats.

This overview chapter provides comparisons and contrasts gleaned from the reports that follow it. The reports themselves provide far greater detail and a more accurate sense of regulation and management of excreta, wastewater sludge, and biosolids in each city, state/province, or country.

It is important to note, however, that measuring, tracking, and reporting quantities and other details is difficult – and compiling data from diverse reports, with diverse measurements (dry weight vs. wet weight, tons versus cubic meters vs. yards) is even more of a challenge. There is, therefore, lack of data – especially in developing countries.

In many higher-income countries, regulations now require standardized reporting to a central agency; however, often the compilation of that data is not done very often or very well. The best data usually come from independent surveys that collect information only from the largest facilities, such as reported from Brazil (Andreoli et al.),[1] where one national study reached 275 of 984 wastewater treatment facilities. In South Africa (Snyman), the data reported is from "a countrywide survey of 72 wastewater treatment plants" out of approximately 900.

What makes the data presented in this *Atlas* useful, despite these limitations, is the fact that the largest facilities produce the vast majority of the wastewater sludge – and they are the ones that are most closely surveyed and understood – and the authors providing the reports are experts in their fields in their countries. Thus, the data are certainly adequate for providing an accurate overview of current production levels, practices, and trends around the globe.

1 *Throughout this overview chapter, this format is used to refer to reports from cities, states/provinces, and countries that appear in the subsequent chapters. The author(s) of the referenced report appears in parentheses.*

Moving forward the sustainable and welcome uses of a global resource

INTRODUCTION

Excreta and wastewater sludge are resources. Finding ways to put them to their best uses is part of developing sustainable human communities.

At the same time, excreta and wastewater sludge – if not managed properly – can be dangerous to human health and the environment. They are also the wastes most distasteful to people of all cultures.

How to integrate these opposing concepts is an ongoing worldwide challenge.

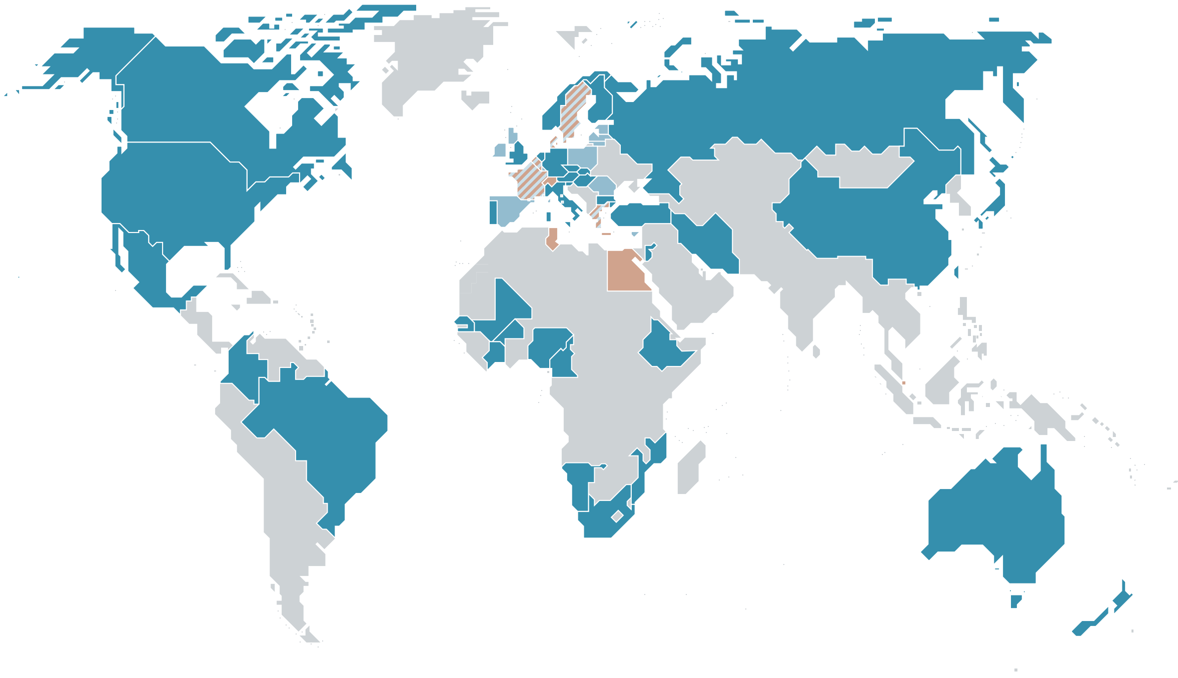
This *Atlas* provides examples of how this challenge is addressed around the globe. The 59 reports that follow this overview chapter provide insights into the similarities and differences in the management of excreta, wastewater, and biosolids in 37 countries. While this compilation of information includes specific information from only 19% of the member states of the United Nations, it includes representation of diverse countries and the full spectrum of management programs.

This overview chapter is a summary, integrating what is reported in the chapters that follow. It is not a comprehensive review of the state of the science or of the literature around the world. Instead, it – and the reports from around the world that follow – provides a broad overview of excreta, wastewater sludge, and biosolids management on Earth – a "big picture" of how we humans manage this "waste" that is a resource.

In 1996, the International Association on Water Quality published *A Global Atlas of Wastewater Sludge and Biosolids Use and Disposal,* edited by Peter Matthews. It included many of the countries found in this volume, allowing for some comparisons between then and now. It also included countries that do not appear in this *Atlas*: Belgium, Denmark, Egypt, France, Greece, Singapore, Sweden, Switzerland, and Tunisia. Some of these countries are included in discussions, below.

The countries in this *Atlas* and the first edition include high, moderate, and low-income countries and countries at various stages of development and with diverse political and social situations. These countries are in the south and in the north, in warm climates and cold, dry, and moist. They all have urban, suburban, peri-urban, and rural areas in which needs vary.

Figure 1. Map showing countries represented in the *Atlas*



Based on UN map no. 4136 rev. 5, September 2006. © United Nations

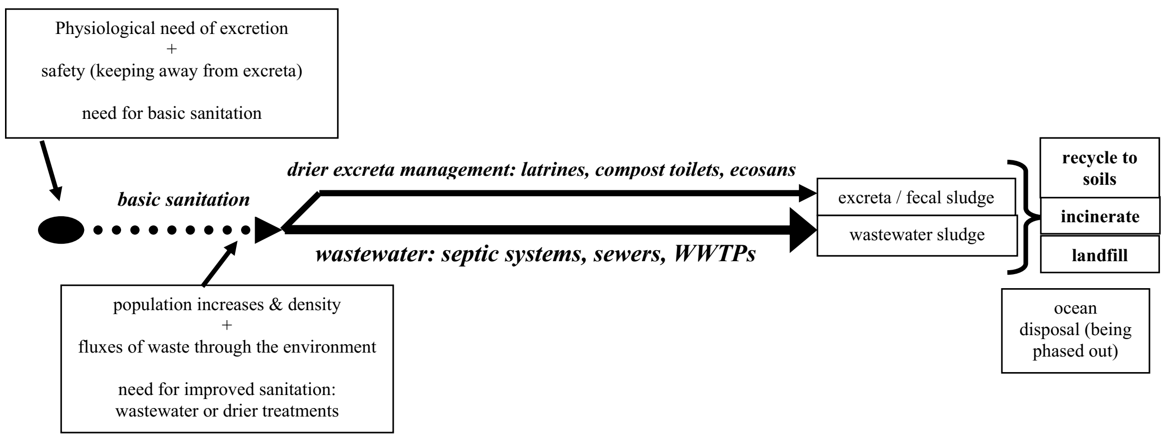
The people in these countries – and all countries – share the same need for sanitation.

This overview chapter compares and contrasts excreta, wastewater sludge, and biosolids management technologies and systems. This discussion builds on the following premises:

- *The creation of wastewater in human communities is inevitable.* Around the world, in all cultures, water has been, and likely always will be, put to use for cleaning and conveying wastes. Even where there are waterless sanitation systems, such as composting toilets, water is used in other ways for cleaning and conveying wastes (consider, for examples, graywater and drainage or stormwater). Even without human involvement, rainwater serves as a natural conveyor of wastes. Wastewater is unavoidable, and, especially where populations are dense, unmanaged wastewater has impacts.
- *Around the world, history shows a common progression of improving wastewater treatment and wastewater sludge management.* This progression, which is an integral part of development, has occurred historically in developed countries and is currently progressing in the developing world.
- This progression appears to be inevitable. At first, it is driven by a need for humans to avoid contact with, and accidental ingestion of, pathogens in human excreta. Over time, there are improvements to systems that move excreta away from human contact. Such improvements become more essential in densely populated areas where the assimilative capacity of the natural environment (e.g. rivers, oceans) is exceeded. More complex systems are required, and most depend on water. They convey excreta and other wastes in sewers that lead to lagoons, septic systems, and wastewater treatment facilities.

- Once such systems are established and are protecting humans from the immediate threat from waste-borne pathogens, focus inevitably shifts toward the effects of wastewater on other human communities downstream and on the natural environment and other organisms. Control of pathogens is no longer the only concern. The discharge into the environment of nutrients (especially nitrogen and phosphorus), heavy metals, and toxic chemicals must also be controlled, requiring more complex systems and technologies – especially in densely populated areas.
- Eventually, as wastewater treatment systems are able to reduce all forms of pollution in wastewater by 90% or more, the volume of wastewater solids – sewage sludge – becomes large and significant and requires careful management. In much of Europe, North America, Japan, and other developed urban areas around the world, the management of wastewater sludge has become a major focus and, in many places, is currently the most debated challenge in the field of sanitation.
- *While developed countries address the concerns of wastewater sludge management, +/-2.6 billion of the world's people lack basic sanitation.* They live in areas where the development of robust systems for excreta management that fully protect public health are nonexistent or in their early stages.
- *Inevitably, the progress that less-developed communities must make during the coming years to improve human health and safety – as set forth in the Millennium Development Goals – will lead to the creation of more fecal sludge and wastewater sludge that must be managed.*
- The continuing refinement of best management practices for excreta, wastewater, wastewater sludge, and biosolids must eventually provide sustainable solutions that work in a diversity of locations and situations around the globe, are energy and cost-efficient (putting these resources to their best uses), minimize transfers of potentially hazardous constituents to the environment, mitigate greenhouse gas emissions, and ensure healthy natural ecosystems.

Figure 2. The inevitable progress of excreta, wastewater sludge, and biosolids management



Thus, this *Atlas* looks at the full spectrum of development of the management of human excreta, wastewater, wastewater sludge, and biosolids. The systems discussed in the following reports have the same goals: improving public health and protecting the environment for the betterment of human communities. How they each go about it varies considerably, and different choices are made in different communities. However, there are also many similarities, and there are a limited number of options for how to manage excreta, septage, and wastewater sludges.

In sub-Saharan Africa and parts of Asia and Central and South America, wastewater treatment systems, if they exist, are minimal or function poorly, and basic sanitation is the focus.

In eastern Europe, Turkey, the Russian Federation, Mexico, South America, and other areas, wastewater treatment has advanced, but wastewater sludge and biosolids management are only now becoming increasingly important concerns, and more complex regulatory structures are being developed.

In Europe, North America, Australia, and New Zealand there is more focus on how to improve the management of wastewater sludge and biosolids. In these places, wastewater is generally treated at the secondary, and, in many cases, tertiary level, and biosolids technologies and regulatory systems are complex. Diverse water quality professionals, engineers, scientists, agricultural experts, and government regulators are refining ways to improve efficiencies, maximize utilization of beneficial aspects, and reduce potential impacts of managing biosolids. There are myriad details being addressed: pharmaceuticals and personal care products (PPCPs) in treated water and biosolids, other trace chemicals and heavy metals, reactivation of pathogens in some particular biosolids treatment scenarios, energy efficiency, and greenhouse gases (from the perspectives of both production and mitigation).

Notably, throughout the development of excreta, wastewater, wastewater sludge and biosolids management – from the least developed to the most developed countries – there are inevitable public concerns about how best to manage this "waste" that is also a resource. Putting biosolids to their best uses in each local situation is the goal of most of the programs discussed in the following reports. That is the goal of many sanitation and water quality experts. But the general public has other goals: avoiding the waste and the odors it can produce. There is a natural aversion to fecal matter and anything associated with it. Conflicts arise when experts propose recycling this "waste," usually in a treated and tested form commonly called "biosolids," back to soils in communities.

Managing excreta and wastewater sludge to produce recyclable biosolids involves many technical challenges. But equally significant are these social, cultural, and political challenges. Funding is required to build infrastructure – and, around the world, the public is the source of funding, either through taxes or sewer usage fees. In order for proper sanitation to be built and operated, complex community sanitation agencies with support from state, provincial, and national governments are needed. To create this infrastructure and organizational support, the public must be educated.

So, even as scientific research and technology advance the management of excreta, wastewater sludge, and biosolids, so too must public understanding and political support be advanced. This *Atlas*, published in the International Year of Sanitation, is intended to educate not only wastewater engineers, sanitation agencies, and biosolids managers, but also political leaders, the media, and the general public.

"Readings from The Visible Past, by Michael Grant, indicate that hygiene in the Roman World was limited to the rich and famous, except for those who could afford the public baths or thermaes, as running water did not reach the poor's tenements from the aqueducts; these lesser folks relieved themselves in pots or commodes which were emptied into vats located under staircases and these emptied into cesspools throughout the city. The rich and famous, from the emperor on down, enjoyed running water in palaces and mansions from lead pipes connected to the aqueducts. At Pompeii, for instance, all houses except the poorest had water pipes fitted with taps, and the waste water was piped away into sewer or trench."

source: http://ancienthistory.about.com/library/weekly/aa031303a.htm

"Long before it invented the compass, fireworks, paper and moveable type, China mastered the technology of the toilet… A 2,000-year-old toilet with a stone seat, armrest and drain for running water was recently discovered in a tomb in central China's Henan Province, according to Xinhua News Agency. 'This top-grade stool is the earliest of its kind ever discovered in the world, meaning that the Chinese used the world's earliest water closet which is quite like what we are using today,' Xinhua quoted archaeologists as saying. The toilet is believed to date from the Western Han dynasty (206 BC to AD 24)."

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source: http://findarticles.com/p/articles/mi_m0WDP/is_2000_July_31/ai_63803935

EXCRETA, WASTEWATER SLUDGE, AND BIOSOLIDS MANAGEMENT IN THE GLOBAL CONTEXT

The following trends describe human civilization and the global environment in the first decade of the 21st century:

Urban and peri-urban populations are expanding rapidly, especially in developing countries. "According to the World Resources Institute (WRI), urban populations in the developing world are growing at 3.5 percent per year, compared to a less than 1 percent growth rates in developed world cities. UN-Habitat says that a staggering 95 percent of the expected global population growth we will see over the next 2 decades will be absorbed by cities in the developing world. What that means is by 2030 another 2 billion people from the developing world will be living in cities (only 100 million from the developed world meanwhile will be doing the same). Currently 75 percent of world's poorest people – 1 billion – live in cities" (CNN, 2008).

Natural resources are being depleted; for example, economically recoverable phosphorus is expected to run out by the end of this century, and agricultural soils are depleted in organic matter and nutrients and subject to erosion.

Increasing numbers of people are demanding more from limited supplies of potable water, not only in developing countries, where 1.1 billion people are without access to safe drinking water, but also in developed countries.

Public health and expected longevity are increasing in most parts of the world; however, there are large segments of the global population still afflicted with diseases that have been eradicated or controlled in developed countries.

The climate is warming, and human influences are causing a portion of this warming. Weather is being affected, and it is predicted that climate-related natural disasters, such as hurricanes and droughts, will become more severe in some areas in the next several decades.

Technology is advancing at an increasing rate, providing improvements in health and welfare in many parts of the world, while also creating increased disparities between rich and poor, the educated and the less-educated.

The changes wrought by these pressures on the global environment and human communities create tensions between peoples and contribute to conflicts.

In this context, managing excreta, wastewater sludge, and biosolids can be massively challenging.

For example, at the local level, figuring out how to install and operate basic latrines in an urban slum requires extraordinary efforts in governance and cooperation as well as technical ingenuity.

Similar challenges are faced in communities in developed countries that are struggling with how best to manage treated biosolids. The difference between the two scenarios, of course, is that the first addresses much greater risks to human health than does the latter. Yet in both situations, the effort is important and the goals are the same: protect public health and the environment to the extent possible within the constraints of the local economy and society. Doing this requires seeing excreta and wastewater sludge as resources that, when properly managed, can help address environmental concerns.

Recognizing a resource

Human excreta are made up mostly of urine and excrement that include diverse complex molecules derived from foods and bodily processes – carbohydrates, sugars, fats, etc. These molecules include common nutrients – such as nitrogen (N) and phosphorus (P) – and micronutrients – such as copper, iron, nickel, and zinc – that are important for the growth of plants. Thus, excreta – commonly called "nightsoil" – has been used as fertilizer in some parts of the world for millennia, and treated excreta and treated wastewater sludge, or "biosolids," are widely used in agriculture around the world today.

Excreta and biosolids contain substantial concentrations of organic matter, which is critically important to the health of soils. Natural cycling of nutrients and energy in ecosystems involves the decay of organic matter in the soil, which releases the elements needed for new plant growth. The organic matter in excreta and biosolids can be valuable additions to this natural process. Excreta and biosolids contain anywhere from 20% to 80% organic matter, depending on their source and the level of treatment.

Conventional agriculture, with tilling and application of chemical fertilizers, is practiced today in most parts of the world. Tilling exposes soil to erosion by wind and water. Chemical fertilizers provide no organic matter. Excreta, wastewater, septage, and biosolids can be an antidote to these agricultural practices. They work like animal manures, agricultural residues, and composts – boosting soil organic matter content and nutrient reserves.

The organic matter in excreta and biosolids also contains energy in the form of chemical bonds. This energy can be released by oxidation, or burning. Thus, excrement from other species (cow dung, yak dung) has long been used as a fuel. The energy value in wastewater sludge or biosolids can be as high as 20 megajoules (MJ)/dry kg, more or less, depending on the percentage of organic matter.

The other major resource available from human waste management is water – if water has been used to convey excreta. In many developed countries with extensive wastewater treatment infrastructure, the water that is cleaned is increasingly being used to recharge aquifers, irrigate crops, and replenish surface water resources.

Other resources in excreta and biosolids are:

- *inert particles* of sand and grit, etc. that remain as ash or slag after excreta or biosolids are burned; the discussion of wastewater sludge management in Japan (Fujiki et al.) notes that more than 20% of the country's wastewater sludge is used in cement and as melted slag in fill.
- *binding sites*: elements and molecules (specifically aluminum and iron oxides and organic matter) that are available to adsorb – or bind – potentially toxic elements such as lead; this characteristic of biosolids has been put to use in a variety of places, including Leadville, Colorado, USA (Stefonick and Hull).

Reduce, Reuse, Recycle

Worldwide, the environmental paradigm is to eliminate the concept of waste and replace it with the concept of recycling of resources. As noted in the 1996 *Global Atlas of Wastewater Sludge and Biosolids Use and Disposal* in a report from Denmark, the commonly accepted hierarchy is (from best to least favorable option):

"1. Prevention of waste generation (avoidance, minimization),

2. Reuse of materials or components,

3. Energy recovery by incineration or gasification, and

4. Disposal (this has very low priority)."

Focusing on this "reduce, reuse, recycle" paradigm has resulted in increasing beneficial use of biosolids in many parts of the world. Indeed, even in countries where most biosolids are disposed of in landfills, such as Jordan (Al-Hmoud) and Turkey (Filibeli), research is being done to find ways to increase agricultural uses. Reports in this *Atlas* from other countries, including Portugal (Duarte) and Slovakia (Sumna), also focus on efforts to increase use of biosolids in agriculture.

ways of using biosolids other than land application in agriculture:

Land reclamation

- land reclamation of minelands (metal mines, aggregate/sand/gravel mines, coal mines)
- landfill closures (as a component of topsoil in closure activities)
- lime stabilized biosolids to mitigate acid mine drainage
- remediation/bioremediation (e.g. with compost or Fe-rich biosolids) of urban/suburban contaminated sites
- general topsoil manufacturing for other uses (in combination with other residuals, such as paper mill residuals)
- restoration and development of water features (e.g. wetland establishment/enhancement; shoreline restoration)

Horticulture and landscaping

- compost feedstock
- potting mixes
- fertilizers (e.g. heat-dried pellet fertilizer)
- sod production
- lawns, parks, sports fields
- green roofs
- erosion control (e.g. compost berms)
- treatment of stormwater flow (compost filters, filter socks)
- highway right-of-way revegetation;
- using incineration ash for phosphorus and liming value in soil mixes
- tailored soil products

Forestry

- forest fertilization (i.e. in existing stands and for reforestation)
- applications following forest fires
- intensive silviculture for fiber crops (e.g. hybrid poplar, trench applications, etc.)

Industrial processes

- use in cement kilns
- making brick or other building materials
- making glass aggregate used in pavement, etc.
- daily or final landfill cover

Resource recovery from biosolids

- biosolids as source of minerals and metals (e.g. struvite production)
- substrate for high value products (e.g. proteins, elements – such uses are experimental still)

Energy recovery

- bioenergy from digestion (in digesters or deep bores, etc.)
- incineration (thermal oxidation or thermal conversion) with heat recovery and/or electricity generation
- gasification, pyrolysis, and other developing hi-tech energy production options

Developed for the Water Environment Association of Ontario Biosolids Seminar, October 1 & 2, 2007, by Ned Beecher (North East Biosolids and Residuals Association), Marc Hébert (Ministèrre du development durable, de l'environnement, et des parcs), and Mike Van Ham & Mark Teshima (Sylvis Environmental).

Landfilling

However, as Ellison and Jefferson note in their report on Canadian wastewater management (see their chapter, below), "Historically, sewage sludge has been considered a waste – to be somehow disposed of and…generally at the least cost possible."

Land disposal – dumping – has often been the least expensive option, in monetary terms and/or in terms of "hassle." In the reports from developing countries, below, dumping untreated excreta, septage, and wastewater sludges on land is common. Sometimes it is dumped in a hole, sometimes just on the surface. Such dumps, if they grow large enough, have environmental and public health impacts. This leads to development of managed landfills.

Modern landfills are not as cheap and easy as methods of disposal. In developed countries, landfill space is becoming more expensive as regulations make siting and operations more costly. In almost all countries, wastewater sludge must be dewatered to at least 15-20% solids prior to landfilling, to avoid excessive generation of leachate and for landfill stability. While dewatering is costly, this is often the only requirement for placing wastewater sludge in a landfill. Excreta and wastewater sludges disposed in landfills are generally not treated further, nor are they tested for contaminants. Therefore, in developed countries, landfilling is the cheapest option in some areas, but it is not in many other areas.

Landfilling is especially easy if there is public concern about incineration or recycling of biosolids to soils. Often the public prefers that anything associated with human excreta and associated societal wastes be managed out of sight and out of mind. Public pressure is part of the reason that, for example, large numbers of smaller wastewater treatment plants – and a few larger ones – landfill 30% of the wastewater sludge produced in the USA (Beecher). There, and elsewhere around the world, many wastewater sludges of high quality are landfilled, even though they come from communities in agricultural areas with little or no industrial activity or other potential sources of contaminants.

But while landfilling may be cheap and easy, in the reports in this *Atlas*, landfilling is widely recognized as a less desirable practice and is being discouraged in many places. This is the perspective shared by environmentalists worldwide. Notes Wong in his report from Hong Kong, China: "disposal of biodegradable waste (including sludge) at landfills is not considered a sustainable waste management practice and not in line with the worldwide trends". Wastewater sludge disposal in landfills is legally banned in some jurisdictions, including several European Union (EU) countries (Germany and France; however, in the latter it is still tolerated). The EU is expected to continue to encourage phasing out the landfilling of all organic residuals.

Where landfilling is not banned, but is being discouraged, governments impose additional restrictions or taxes. Québec (Hébert and Groeneveld) charges Can $10.41 (U.S. $10.50) per ton for landfill disposal. In Austria (Kroiss), wastewater sludge cannot be landfilled unless it contains less than 5% total organic carbon by dry weight (i.e. it is not very organic and putrescible) and it has less than 6000 mega joules (MJ) of energy per kilogram dry weight (i.e. it is not valuable for energy production).

There is current research investigating the concept of "bioreactor" landfills. For example, the report from Grand Rapids, Michigan, USA (Lunn) emphasizes that wastewater sludge placed in a well-managed "bioreactor" landfill results in increased generation of methane, an alternative fuel that offsets the need for fossil fuels. Whether or not this is an environmentally sound and sustainable management strategy is in question, however, if greenhouse gas emissions are taken into consideration. The problem is that excreta and wastewater sludges tend to decompose quickly and, therefore, when placed in a landfill, generate some methane during active landfilling when methane is not captured – even in a bioreactor landfill. As discussed below, methane is a powerful greenhouse gas, and one of the goals of excreta and wastewater sludge management today is to reduce its emission into the atmosphere. Anaerobic digesters, which are widely used worldwide for treating wastewater sludges, are far more efficient systems for producing methane gas while limiting fugitive emissions.

Incineration

Incineration greatly reduces the volume of excreta and wastewater sludge by rapidly oxidizing the organic matter, and it can take advantage of the energy in these materials. Incineration, however, requires a large capital investment in infrastructure and requires fuel – usually fossil fuel – to create the burn. Incinerators in more developed countries are subject to increasingly strict air pollution control standards, which require increased complexity and costs.

Despite these disadvantages, incineration of wastewater sludge has become standard practice in large, densely populated areas of some technologically advanced countries. Japan (Fujiki) incinerates more than 70% of its wastewater sludge; in the Netherlands (Kreunen) and Germany (Schulte), the rates are 58% and 34%, respectively. Slovenia (Grilc) dries much of its wastewater sludge and then sends 50% out of country for disposal in incinerators. In Canada, about ⅓ of the sludge is incinerated, and in the USA, 15%, mostly in larger eastern cities like Cleveland (Dominak), where incineration results in a relatively low cost for sludge disposal – about $25 per dry tonne, including the value of energy recovered.

As fossil fuel prices have risen dramatically in recent years, the interest in biosolids as an alternative fuel has also increased. This has pushed many incineration facilities to begin to recover heat to generate electricity and provide warmth to facility processes like digestion and interior spaces.

But incineration is not always publicly accepted, as noted in the report from Portugal (Duarte). And the capital and operational costs of incineration facilities precludes smaller cities from building them. Only Hong Kong (Wong), which has a minimal amount of agricultural land and has been landfilling 100% of its wastewater sludge in recent years, reports a deliberate policy shift toward incineration (with energy recovery). Several EU countries and Japan are exploring other high-technology thermal treatments, such as gasification and pyrolosis, with the hope of obtaining more net energy from wastewater sludge than standard incineration yields.

Around the world, the ash resulting from incineration of wastewater solids is usually disposed of in landfill. But, as wastewater and biosolids management professionals focus on recovering resources to the greatest extent possible, ash is increasingly being put to use as fill material in construction projects or as an ingredient in cement. For example, in Yokohama, Japan (Kawai), 110,000 cubic meters of improved soil are produced each year using 7,000 cubic meters of wastewater sludge ash as one ingredient; testing shows the end product to have "essentially the same characteristics as pit sand designated by road works administrators as backfill material."

Uses of biosolids on soils

The value of biosolids use on soils has been demonstrated through extensive research in many countries. For example, in the report from Brazil (Andreoli et al.), recent research is mentioned that shows significant increases in crop yields from the use of biosolids to fertilize corn.

However, overcoming natural human concerns about the use of materials derived from excreta and wastewater requires local advocates and research and demonstration projects. Even in parts of the world where biosolids have been used on soils for decades – such as England (Matthews), the USA (Stevens), and Canada (Ellison and Jefferson), research continues. As Ellison and Jefferson note: "biosolids are not yet generally recognized in Canada as a valuable environmental resource, and a resource that can contribute to a number of environmental sustainability efforts…"

Markets have been recognizing the value of biosolids for many years. In the 1996 *Global Atlas of Wastewater Sludge and Biosolids Use and Disposal*, Tianjin, China (Chen) reported that farmers were paying 5-10 yuan (US $0.60-US $1.20) per tonne of biosolids, above and beyond transport costs. In that earlier *Atlas*, France (Robaine and Chabrier) reported a fertilizer firm was selling dried sludge for 150 French francs (~$60) per tonne. Currently in New Zealand (Bradley), Bioboost® fertilizer is sold in 25-kg bags for NZ $15 (US $11.50, or US $460 per tonne). And Denver, Colorado, USA (Stefonick and Hull) reports revenue of nearly $80,000 in 2007 from sales of several thousand tonnes of biosolids compost. People are buying good quality biosolids around the globe. (It is important to note, however, that revenues from sales can only partially offset the sizable costs of treating and managing wastewater sludge properly to make a valued product.)

What farmers, landscapers, and horticulturists value in biosolids products are the nutrients and organic matter. Biosolids use displaces the need for some chemical fertilizer, especially those providing nitrogen and phosphorus. Nitrogen fertilizer is manufactured with copious amounts of natural gas, and phosphorus is mined and must be transported considerable distances to reach most farmers' fields. Recycling local biosolids costs the farmer less and reduces the use of fossil fuels and recycles nutrients and organic matter. The importance of utilizing the nutrients in excreta and biosolids is underscored by the fact that natural phosphorus (P) reserves are expected to be depleted by century's end.

It is clear from the reports in this *Atlas* from around the globe that those involved in managing excreta, wastewater sludge, and biosolids recognize them as resources. They are increasingly interested in using the nutrients, organic matter, and energy in them. These environmental professionals recognize the importance of utilizing every possible resource, if sustainable societies are to be realized.

"It is clear that there is an overwhelming wish to use wastewater solids, particularly in agriculture. In some countries this wish is realized."

– P. Matthews, 1996, A Global Atlas of Wastewater Sludge and Biosolids Use and Disposal

The need and challenge of managing excreta and wastewater sludge

There are, then, three options for excreta and wastewater sludge management:

- disposal on land, preferably in an appropriate managed landfill
- incineration or other thermal process followed by disposal or use of the resulting ash, and
- recycling to soils, preferably after proper treatment and testing to ensure maximum benefits and negligible harm to soils, crops, public health, and the environment.

Doing nothing is not an option.

Excreta and wastewater sludges exist and must be managed, especially in densely populated areas where the volumes are too great to allow for natural assimilation into the environment and space for stockpiling is limited.

"In Brazil, these activities have been lately neglected, accumulating great environmental liability susceptible to lawsuit and fines by environmental agencies. Observing the series of omissions, it starts at the conception of the treatment systems, which ignores the residues management, going through the environmental license agencies during the implementation of new companies and it finally ends up being administrated as an emergency, without adequate planning, causing great environmental impacts and operational costs..."

– C. Andreoli et al., report from Brazil

Human health and environmental pollution

In 2007, *BMJ* (formerly the *British Medical Journal*) conducted an Internet survey to determine what its readers consider to be the greatest medical advance since 1840. The winner, chosen by more than 11,000 respondents, mostly doctors, was *sanitation*. It beat out antibiotics, anesthesia, and vaccines (Hitti, 2007). A contemporary confirmation of this finding was provided in the journal *Science* in 2006: Grassly et al. determined that the failure to eradicate polio in India is due, in large part, to a lack of sanitation that renders the widely-used polio vaccine ineffective.

Basic sanitation is a necessity for health and dignity. It is taken for granted in developed countries. But there are 2.6 billion people without it. In the Millennium Development Goals (MDGs), Target 10 states: "Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation." Whether this goal will be reached is uncertain. Information provided by the International Year of Sanitation 2008 (IYS) (*http://esa.un.org/iys/*) notes:

> *"The estimated $10 billion annual cost to halve the proportion of people without basic sanitation by 2015…is modest and affordable. If sustained, the same investment could achieve basic sanitation for the entire world within one or two decades. This sum is less than 1% of world military spending in 2005, one-third of the estimated global spending on bottled water, or about as much as Europeans spend on ice cream each year."*

This *Atlas* focuses attention on one critically important aspect of sanitation: what to do with the excreta, septage, and wastewater sludge that are an unavoidable result of proper sanitation. As efforts to address the lack of sanitation proceed, planning needs to include proper treatment and recycling or disposal of these materials.

While the harmful health effects of lack of basic sanitation are clear, many people do not appreciate the comparative risks of various stages of excreta, wastewater sludge, and biosolids management. The fact is, the inevitable development of improved sanitation results in increasingly reduced risks to human health and the environment. Thus, in developed countries today, the risks being addressed by the latest developments in biosolids management are far smaller risks than those being addressed with basic sanitation in developing countries.

Research and experience suggest the following hierarchy of risk to human health:

living in a dense community without basic sanitation > (is more risky than…)
irrigation of crops with untreated, pathogen-contaminated wastewater >
use of untreated, pathogen-contaminated excreta or wastewater sludge on soils >
use of untreated, pathogen-contaminated animal manures on soils >
use of treated manures, wastewater, or biosolids on crops >
use of these treated materials in accordance with strict modern regulations that address heavy metal and chemical contaminants

As sanitation has developed over decades, the initial focus has been on reducing the immediate threat from pathogens. Barriers to infection are established. Then focus has broadened to include managing septage and wastewater sludge. Then focus has broadened further to include refinements that yield additional, but smaller reductions in risks to human health: controlling heavy metals, chemical contaminants, and nutrients in wastewater and wastewater sludge so that the use or disposal of these materials does not have negative impacts on the environment.

While basic sanitation and avoiding spread of pathogens is the critical focus of sanitation work in developing countries, heavy metals and chemicals have been the recent focus of research and public concern with regards to wastewater sludge management in developed countries. It is important to emphasize the difference in relative risk to public health and the environment from these. Pathogens present acute, immediate risk:

Because of lack of adequate sanitation and transmission of pathogens, a child dies every 20 seconds (IYS, 2008).

In 2000, the leading public health news story in Canada was about drinking water contaminated with the O157:H7 strain of *E. coli* bacteria from cattle manure in farm runoff that caused about 2,500 illnesses and seven deaths in Walkerton, Ontario (CTV.ca).

In 2006, the leading public health news story in the United States was about spinach contaminated with *E.coli* O157:H7 that resulted in 205 confirmed illnesses and three deaths. The identified risk factors were "presence of wild pigs, the proximity of irrigation wells used to grow produce for ready-to-eat packaging, and surface waterways exposed to feces from cattle and wildlife" (U.S. Food & Drug Administration, 2007).

In comparison, the present concerns in developed countries about chemicals and controlled levels of heavy metals in biosolids present smaller risks. For example the USA National Academy of Sciences (1996 and 2002) found that there is no documented scientific evidence that the 1993 USA regulations for treatment and management of sewage sludge have failed to protect public health. These regulations are based on assessments of the potential risks from pathogens, heavy metals, and some chemicals found in biosolids

Pathogens

The greatest short-term danger to humans from untreated excreta, wastewater, septage, and wastewater sludge is from pathogens, micro-organisms that can cause disease. The nature of pathogens and how they impact humans is an advanced – and continually advancing – science. Systems for treating pathogens in excreta and wastewater sludge are well developed (e.g. U.S. EPA, 2003) and have been effectively used in diverse countries, climates, and situations for decades.

A global priority in the field of sanitation is to create basic sanitation for the billions who do not have it today. Doing this involves containing and properly treating and managing the resulting excreta, septage, and wastewater sludge to reduce transmission of pathogens.

In developed countries, risks from pathogens are much reduced because of a lower prevalence of the diseases in the populations. In addition, water and wastewater treatment systems and hygienic food handling systems are in place. While constant vigilance and continual research are necessary, few people in these countries die from lack of sanitation and waterborne diseases such as cholera. In these countries, when the properly treated and managed wastewater and biosolids are recycled into the environment for irrigation and as soil amendments, they do not present a significant risk with regards to pathogens.

The same is not necessarily true in developing countries. There, the prevalence and diversity of pathogenic organisms is often higher in sewage than in developed countries, because there is a greater prevalence in the human populations. In addition, wastewater treatment systems may not be as robust. Therefore, use of treated wastewater and biosolids on crops destined for direct human consumption may present greater risk. Thus, many of the reports from developing countries, below, discuss pathogen control and restrictions on uses of biosolids on food crops.

In contrast, in developed countries, current concerns and research on wastewater sludge management include topics such as reactivation and regrowth of pathogens after biosolids treatment, the need for further demonstration of the effectiveness of common pathogen reduction treatments such as anaerobic digestion, the uses of microbial risk assessments, and estimating the potential for transmission of pathogens during land application of biosolids.

Pathogens that affect humans are not the only pathogens of concern. Animals and plants are affected by myriad pathogens, and ways to reduce the transmission of these pathogens have also advanced, thus providing improvements to agriculture. One example is research that has shown that the use of compost in soils growing turf grasses – such as on golf courses – can reduce plant pathogens. Other research has demonstrated that animal manures can have high levels of pathogens – including human pathogens – that must be reduced when manures are used on food crops.

Heavy metals and chemical contaminants

There are two other public health issues involved with the use or disposal of collected excreta, septage, and wastewater sludge: heavy metals and chemical contaminants. "Heavy metals" is a general, common term used to refer to elements (not all of which are actually heavy metals in the periodic table) that, in sufficient quantities, are toxic to humans, animals, and/or plants. Chemical contaminants of concern are those produced in modern society for a variety of uses, including industrial chemicals and byproducts (e.g. PCBs, dioxins, polyaromatic hydrocarbons – PAHs), pesticides and herbicides, and chemicals and byproducts found in common household products (e.g. polybrominated diphenyl ethers or PDBEs, nonylphenol, linear alkyl sulfonate or LAS, musks, pharmaceuticals, etc.).

Low levels of heavy metals and a few chemicals are regulated in modern biosolids. These contaminants, when applied to soils, can harm the environment, especially because basic elements (heavy metals) and persistent organic pollutants (POPs) are likely to remain in the soil indefinitely. Because of this, there has been extensive research around the world into the fate and impacts of these constituents in biosolids and soils. The scientific understanding of heavy metals is particularly advanced, and all of the middle-income and high-income countries reporting in this *Atlas* have in place, or are developing, regulatory standards and management practices that control the levels of these potentially toxic elements in soils. Relative to the risks of harm from unmanaged excreta and wastewater sludge, the risks from heavy metal and chemicals in properly regulated and managed biosolids are considered small.

The reports from the various cities, states/provinces, and countries that follow include much discussion of heavy metals in biosolids. For example, many countries not only control the concentrations of heavy metals in biosolids applied to soils, but also restrict the amounts of particular heavy metals that can be applied within a given period of time. And most countries have limits on the total concentrations of each element in soils, whether they entered the soil from biosolids or another source.

Restricting the total concentration of heavy metals in a particular soil results in a "site life" – that is, the number of years that biosolids containing a particular concentration of heavy metals can be applied to a specific soil before the maximum allowable soil concentration of one heavy metal is reached. Biosolids managers calculate the site life possible for the land application of a particular biosolids product in order to understand how long a particular land application program might continue.

Site life is an important concept, because it means that the concentrations of all heavy metals and all other contaminants in a soil are controlled: in the regulatory structures in most countries, once the concentration of any regulated contaminant reaches the regulatory limit, biosolids may not be applied to that soil again. Thus, at that point, the addition of all contaminants ceases (at least from biosolids).

A site life analysis conducted as an example by Peter Matthews and others showed that Seattle, Washington, USA, biosolids applied at a rate of 10 tonnes/hectare could presumably be applied under USA federal regulatory standards for 159 years and, under European Union directive standards, for 92 years. In this example, in the USA, the limiting metal is lead; in the EU, the limiting metal is copper. What is significant is that, under both regulatory programs, the resulting final soil concentrations of heavy metals would be similar when the site had reached its limit and could no longer be used for biosolids applications. Thus, the on-the-ground effects of EU and USA regulations are more similar than is sometimes assumed.

Table 1. Regulatory standards and measured concentrations of heavy metals from atlas reports

		As	Ba***	Cd	Co	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
	The Benchmark Sludge (discussed by authors in this Atlas to assist in comparisons of regulations)			3			500	200	3		40		1000
South & Central America	Brazil (Conama and Parana) regulatory limits	41	1300	39		1000	1500	300	17	50		100	2800
	Brazil average concentration in wastewater sludge	14,69		10,75		143,72	255,39	80,37	2,35	112,88	41,99	27,24	688,83
	Colombia: Average measured concentrations in biosolids from El Salitre WWTP, Bogota	18,6		76		72,5	163,4	87,5	8		42,9	24,4	1014,2
	Mexico regulatory limits for "excellent" (highest quality) biosolids for general public contact uses (established 2002)	41		39		1200	1500	300	17		420		2800
North America – USA	U. S. EPA best quality ("EQ") standard for general public contact uses	41		39			1500	300	17	(75)*	420	100	2800
	Denver, CO – Average measured concentrations in Class B biosolids / Class A compost	2.6 / 3.9		2 / 2			670 / 699	39 / 37	1.3 / 1.4	20 / 24	16 / 16	14.8 / 12.2	714 / 743
	Los Angeles, CA, Hyperion Treatment Plant – Average measured concentrations in Class B biosolids	6,05		10,2		84	1060	38,5	1,91	17,8	50,8	14,5	1180
	Milwaukee, WI – Average measured concentrations in heat dried biosolids fertilizer pellets in Milorganite ®	8,4		3,9		289	266	57	0,3	11	32	4,4	534
North America – Canada	Ontario regulatory limits	170		34	340	2800	1700	1100	11		420		4200
	Ottawa – Average measured concentrations in biosolids	1		1	6	50	460	51	1		16		593
	British Columbia regulatory limits for Class A biosolids (meets Federal Fertilizer Act)	75		20	150	(1060)**	(2200)**	500	5	20	180	14	1850
	British Columbia – Average measured concentrations in biosolids	4,6		2,3	5,2	50,7	888	56	3,1	7,6	26,4	4,2	588
	New Brunswick regulatory limits			20			850	500	5		180		1850
	Greater Moncton Sewerage Commission – Average measured concentrations in biosolids			0,5			137	27	0,3		9		223

All data are concentrations expressed in mg/kg dry weight.
All data are from reports in this Atlas.
* *there is no EQ standard; this is the non-EQ standard*
** *no Class A stnd; this is Class B stnd*
*** *Ba (Brazil) / Br (Turkey) / B (China)*

		As	Ba***	Cd	Co	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
European Union	1986 European Directive regulatory limits			20-40			1000-1750	750-1200	16 -25		300 -400		2500 -4000
	Czech Republic – regulatory limits in wastewater sludge used in agriculture	30		5		200	500	200	4		100		2500
	Finland – Average measured concentrations in wastewater sludges, 2005			0,6		18,1	244	8,8	0,37		30,3		332
	Germany 1992 Sewage Sludge Ordinance regulatory limits			10		900	800	900	8		200		2500
	Germany proposed new ordinance (2007) regulatory limits			2,5		100	700	120	1,6		60		1500
	Germany DWA survey 2003 – measured concentrations in wastewater sludges			1,52		60,5	380,2	61,7	0,92		32,2		955,7
	Italy 1996 & 2008 regulatory limits (enforcing the European Directive 86/278/EEC)			20			1000	750	10		300		2500
	Italy – Average measured concentrations in Sardinia biosolids used in agriculture, 2006			1,6		22,3	261	76,2	0,2		15,6		577
	Netherlands regulatory limits, 1995	15		1,25		75	75	100	0,75		30		300
	Slovakia regulatory limits in wastewater sludge used in agriculture	20		10		1000	1000	750	10		300		2500
	Slovenia regulatory limits in wastewater sludge used in agriculture	20		0,5		40	30	40	0,2		30		100
	Slovenia – Average measured concentrations in wastewater sludges	2		1	7	90	200	150	2		35		600
Other European Countries	Norway regulatory limits at limited application rate of 20 dt/ha/10 yrs.			2		100	650	80	3		50		800
	Norway regulatory limits for unrestricted uses			0,4		50	50	40	0,2		20		150
	Switzerland regulatory limits, 1996 (use of biosolids on soils is no longer permitted)			5	60	500	600	500	5	20	80		2000
Middle East	Jordan – regulatory limits in Type 1 (highest quality) biosolids	41		40		900	1500	300	17	75	300	100	2800
	Turkey – Average measured concentrations in wastewater sludge from Izmir Guneybati WWTP, 2007		28,4	1,24	26	34,2	70,2	34,2			62,1		300

All data are concentrations expressed in mg/kg dry weight.
All data are from reports in this Atlas.
** there is no EQ standard; this is the non-EQ standard*
*** no Class A stnd; this is Class B stnd*
**** Ba (Brazil) / Br (Turkey) / B (China)*

		As	Ba***	Cd	Co	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
Asia	China regulatory limits for concentrations in sludge applied to soils of pH > 6.5 or < 6.5	75 / 75)	150 / 150	20 / 5		1000 / 600	1500 / 800	1000 / 300	15 / 5		200 / 100		3000 / 2000
	Japan – regulatory limits in Fertilizer Control Law	50		5		500		100	2		300		
	Sapporo, Japan – Average measured concentrations in biosolids compost	7		<1		29	140	10	0,19		35		300
	Suzu, Japan – Average measured concentrations in dried wastewater sludge	8,2		2,2		19,5		5,2	1,1		32,3		
	Russian Federation regulatory limits for high quality wastewater sludge use in agriculture (except cannot be used for mushroom, strawberry, green vegetable)	10		15		500	750	250	7,5		200		1750
	Russian Federation – Average measured concentrations in sludge from Moscow region, 2007	0 – 24		0 – 300		18.2 – 1280	0.9 – 1200	0.8 – 1070	0 – 11.35		1.4 – 306		3.0 – 3820

All data are concentrations expressed in mg/kg dry weight.
All data are from reports in this Atlas.
** there is no EQ standard; this is the non-EQ standard*
*** no Class A stnd; this is Class B stnd*
**** Ba (Brazil) / Br (Turkey) / B (China)*

The scientific understanding of many *chemical* contaminants in excreta and biosolids applied to soils is also well developed. In many jurisdictions, regulatory control of chemicals of known concern – such as pesticides and industrial chemicals ("priority pollutants") – was deemed unnecessary by risk assessments. In the European Union (Matthzews), "after careful consideration it was decided that limits were not needed for trace organics." Similarly, U. S. EPA (Stevens) deemed regulation of dioxins/furans/co-planar PCBs to be unnecessary.

However, current research is exploring the potential fate and impacts of chemicals in common use that may interact with endocrine systems in humans or animals (endocrine-disrupting chemicals, or EDCs). Such chemicals have been shown to have impacts in organisms when they occur in very small concentrations (even parts per billion or less). The presence of chemicals from pharmaceuticals and personal care products (PPCPs) has been widely demonstrated in surface waters of the United Kingdom, parts of Europe, and around North America. They appear in higher concentrations downstream from wastewater treatment facilities. Some are thought to be linked to disruptions of endocrine systems in aquatic animals, an effect that has been demonstrated in laboratories. Some have been detected in biosolids applied to soils, but research is just beginning regarding their fate and effects on soils and associated ecosystems. Initial studies suggest minimal, if any, ecological effects, and impacts to human health through the process of biosolids recycling to soils are unlikely.

Research on these issues should, and will, continue.

Table 2. Regulatory standards for selected chemical contaminants from atlas reports

	Absorbable organic halides (AOX)	Polychlorinated biphenyls (PCBs)	PcDD/F ("dioxins")	Benzo(a)pyrene (B(a)P)
U. S. EPA best quality ("EQ") standard for general public contact uses			none*	
Czech Republic – regulatory limits in wastewater sludge used in agriculture	500	0,6		
Germany 1992 Sewage Sludge Ordinance regulatory limits	500	0.2 (per congener)	100 ng	
Germany proposed new ordinance (2007) regulatory limits	400	0.1 (per congener)	30 ng	1
Germany DWA survey 2003 – measured concentrations in wastewater sludges	186	0,08	10,1	
Slovenia – Average measured concentrations in wastewater sludges	140	<0.05		
Switzerland regulatory limits, 1996 (use of biosolids on soils is no longer permitted)	500			
China regulatory limits for concentrations in sludge applied to soils of pH > 6.5 or pH < 6.5	500 / 500	0.2 / 0.2	100 / 100	3 / 3

All data are concentrations expressed in mg/kg dry weight, except PcDD/F ("dioxins"), which are in ng/kg dry weight.
All data are from reports in this Atlas.
**EPA risk assessment determined no need for dioxin/furan standard in U. S. regulations.*

And, as countries develop more thorough and complex treatment and management systems for excreta, septage, wastewater sludge, and biosolids, they will conduct local research to verify, in their situations, the scientific understanding from other regions.

For example, in Brazil (Andreoli et al.), researchers compared the levels of heavy metals in local biosolids and animal manures: "In a study performed in the metropolitan area of Curitiba concerning the use of sludge in agriculture, Pegorini (2002) evaluated the heavy metals presence in bovine, swine, and poultry manure. He found that the concentration of Cu is slightly superior than Cr, Cd, Pb, and Ni for the biosolids, as the result of industrial activity. In the case of Zn, the values found in the manure are slightly superior in bovine and poultry, but lower in swine. So, it can be supposed that the wastewater sludge does not offer greater health risks than the animal manure that is frequently used in farms."

Commerce in developing countries does not utilize the abundance and diversity of chemicals and heavy metals as in developed countries, so risks from these in excreta and wastewater sludge may generally be lower in such countries. However, as treated excreta and biosolids recycling programs develop, concerns with these kinds of contaminants are possible. Developing countries can learn from the mistakes of higher-income countries and do a better job, from the start, at controlling the use in commerce and discharges of heavy metals and chemicals of potential concern to the environmentally sound management of wastewater and wastewater sludge.

"In general, Mexican municipal sludge has two common characteristics: (a) a high biological content compared to that found in developed countries' sludge… and (b) its relatively low metal content (Jimenez and Wang, 2006) – a common characteristic in sludge from developing countries."

– Garcia et al. in the chapter on Mexico, below

Nutrients

The nutrients found in all excreta, wastewater, wastewater sludge, and biosolids are the reason these materials are valuable for growing crops. Urine contains most of the nitrogen in excreta. Fecal matter contains abundant complex organic matter and nutrients. When processed through a biological treatment process, such as secondary wastewater treatment, additional organic matter is generated. Typically, wastewater sludge contains the following percentages of the major plant nutrients: 1-8 % nitrogen (N), 0.5-5 % phosphorus (P) as P_2O_5, and <1 % potassium (K) as K_2O (Table 3).

Table 3. Major nutrients in representative wastewater sludges and biosolids

	N (%)	P2O5 (%)	K20 (%)
The Benchmark Sludge	3.5	3.5	0.2
Australia: Perth average biosolids (Gale)	7.4	1.8	0.97
Brazil average wastewater sludge (Andreoli et al.)	5.75	1.82	0.36
Canada: Greater Moncton Sewerage Commission average biosolids (LeBlanc and Richard)	2.1	0.5	0.1
Finnish average wastewater sludge (Rantanen)	3.4	2.4	no data provided
Italy: Sardinia, average biosolids used in agriculture (Spinosa)	5.2	1.4	no data provided
Turkey: Izmir Guneybati WWTP average wastewater sludge (Filibeli)	1.68	0.68	0.49
USA: Milwaukee, WI Milorganite® (Schlecht)	5.8	4.35	0.43

Data are in percents dry weight and are from reports in this Atlas.

Utilizing these organic materials has environmental benefits over use of chemical fertilizers. Most importantly, the nutrients in excreta, manures, and biosolids are held in complex molecules and do not become available to plants or susceptible to runoff or leaching until soil microbes break down the molecules. Thus, applying biosolids to farm soils reduces the risk of the nitrate form of nitrogen leaching to groundwater in comparison to the use of chemical fertilizers.

Besides the major plant nutrients, biosolids also provide numerous micro-nutrients to soils and plants, such as copper, nickel, molybdenum, and zinc. Although these heavy metals are regulated in biosolids in developed countries, they are important nutrients in smaller amounts. In some farming situations, the addition of micronutrients in biosolids is the predominant reason for increased crop yields in comparison to the use of chemical fertilizers.

While nutrients are critical to plants and animals, nutrients in the wrong place at the wrong time can be detrimental to ecosystems. Nitrogen (N) in drinking water (greater than 10 mg/L, according to U. S. EPA standards) can be a human health risk. Excess nitrogen stimulates undesirable growth in marine ecosystems. Excess phosphorus in fresh waters increases eutrophication and associated reductions in dissolved oxygen necessary for aquatic species.

Therefore, proper management of excreta, wastewater sludge, and biosolids is an important part of protecting water quality. Regulations and best management practices are used in many parts of the world to ensure that the nutrients in excreta and biosolids reach the plants that can utilize them, but are not applied in excess so that they leach to groundwater or run off to surface waters.

For example, Rupke reports that in Ontario, a new Nutrient Management Act will require control of nutrients from on-farm and off-farm sources, including from biosolids. Norway (Blytt) manages the recycling to soils of all organic residuals (animal manures, food wastes, and biosolids) in an integrated regulatory program. Another example of nutrient management is discussed by Stefonick and Hull: when there is drought at the Denver, Colorado, USA land application sites, the amount of biosolids applied is reduced. This is to avoid having excess N in the soil. Such holistic approaches to nutrient management are likely to become more common around the world.

Because of their relative abundance in biosolids (measured in percentages) compared to heavy metals or other contaminants (measured in parts per million), nutrients are usually the factor that limits applications of biosolids to soils. Indeed, the European Union, the United States, and many other regulatory systems restrict applications of biosolids to soils to the "agronomic rate" – the amount of biosolids that supplies the amount of nitrogen needed, on an annual basis, by the crop being grown. This restriction ends up meaning that biosolids are applied to soils at relatively low rates, resulting in very slow accumulation in soils over time of any heavy metals and other persistent contaminants (Table 4). In addition, many countries have regulations that stipulate annual and cumulative trace element loading rates and post-application soil quality parameters, providing further control over application rates.

Calculating the agronomic rate involves taking into account the amount of each nutrient that is released each year by the microbial activity in the soil; many developed countries have formulas based on local research for making these estimations. For example, the report from Australia (Gale) notes "The application rate for nitrogen assumes that 15% of the total nitrogen is mineralised whilst phosphorus is assumed to have 21% available P to the plant."

As Kroiss notes in his report about Austria, regulations for protecting surface water quality are becoming more stringent. This means that wastewater treatment plants must remove more nitrogen and phosphorus (P) from sewage, resulting in higher concentrations in wastewater sludge. This is a benefit for local agriculture, Kroiss explains, and he estimates that ~40% of the P fertilizer imported into Austria could be replaced by this local resource. Several papers presented at the IWA Specialist Conference on biosolids in Moncton, NB (June 2007) focused on recovering P from biosolids, in the form of struvite (a P-rich mineral).

Table 4. Land application rates in various conditions and countries

Country or other jurisdiction	Regulatory maximum application rate (dry tonnes / ha)	Typical application rate used in practice (dry tonnes / ha)
Australia (Gale), use in broad-acre agriculture		8 (dewatered cake) 13 (lime-stabilized biosolids)
Canada: British Columbia forest application of benchmark sludge		84 (hybrid poplar) 40 (Douglas Fir)
Canada: GMSC, New Brunswick (LeBlanc and Richard) agricultural lands	8 (once every 3 years)	
Canada: Ontario (Rupke) agricultural lands	22 (over five years)	
China (He) agricultural lands	30 (per year)	
England (Matthews)		6 to 8
Jordan (Al-Hmoud) agricultural lands	6	
Norway	varies (usually just once every 10 years)	
Russian Federation (Gunter and Belyaeva) forestry use		60 to 80
South Africa (Snyman) agricultural applications with high quality wastewater sludges	10 (per year)	
USA: Denver, Colorado		2 to 3 (dryland wheat) 18 to 22 (irrigated wheat)
USA: Kent County, Delaware biosolids use in agriculture		3 to 10 (depends on crop and soil type)

"[S]ludges contain organic matter and nutrients, derived mainly from domestic wastes, and heavy metals and organic contaminants from industrial wastes…[T]he correct management of wastewater sludge requires the development of 'multiple and diversified options and strategies, which is a combined challenge common to city administration, citizens and industry. First, these groups should aim at reducing the amount of sludge produced by emphasizing better sewerage and treatment works design and more prudent consumer behavior. Secondly, higher-quality sludges should be produced by stricter control of industrial contamination. To this end, cities without, or with limited, sewerage should not repeat the mistakes made by developed countries of first contaminating sludge owing to limited industrial discharge control, and then slowly improving its quality by introducing efficient industrial control. They should impose strict controls right from the beginning and thus produce sludge with nutrients that can be recycled without risk of contaminating soil or plants."

– Lue Hing et al., 1996, A Global Atlas of Wastewater Sludge and Biosolids Use and Disposal

Odors and nuisance concerns

Odors – bad odors – are the most common trigger of complaints affecting programs that manage excreta, wastewater sludge, and biosolids. While the issues discussed above – pathogens, heavy metals, and chemicals present demonstrated risks that must be managed, malodors present little or no risk to public health or the environment, but still have to be carefully managed if programs are not going to be shut down by an upset public.

In Québec, Canada (Hébert and Groeneveld), this concern has led to elevation of odor concerns into a regulatory standard alongside heavy metals and pathogens: each biosolids material is given an odor classification, and those with particularly bad odors are restricted in their uses. The report from Suzu, Japan (Takai et al.) makes mention of odor control equipment, which is common at wastewater treatment and wastewater sludge management facilities in developed countries around the globe. Likewise, Australia (Gale) mentions new "state-of-the-art" odor control systems at wastewater treatment plants in Perth. Odor control has become a significant part of the necessary infrastructure for wastewater sludge management – despite the fact that it is mentioned in only a few of the reports included in the following chapters.

Other nuisances that plague wastewater sludge management programs in the developed world include trucking operations, dust and noise at rural biosolids use sites, compaction of farm soils, and truck traffic and its impacts on roads. The National Biosolids Partnership's Environmental Management System (EMS) program in the USA, which involves biosolids management going above and beyond regulations, addresses these kinds of issues, helping reduce the numbers of upset neighbors and complaints. For example, one of the results of the EMS program at Lawrence, Kansas, USA (Klamm) has been improved digestion that resulted in decreased odors.

As excreta, wastewater sludge, and biosolids management programs advance, malodors and other nuisance concerns must be addressed if public support is to be maintained.

Climate change

The climate of Earth is warming, and there are increased incidences of extreme weather and shifts in general weather patterns. Human influences are causing a portion of these changes. Climate change science, mitigation strategies, and adaptations to inevitable global warming are common topics in the media and in policy discussions worldwide, from the national to the local level. How do the management of excreta, wastewater, and wastewater sludge affect climate change?

Greenhouse gas emissions

Methane (CH_4) and nitrous oxide (N_2O) are greenhouse gases (GHG) that have a stronger global warming effect in the atmosphere than carbon dioxide. Methane and nitrous oxide are formed when organic materials – such as excreta, wastewater, wastewater sludge, and biosolids – decompose in anaerobic (or almost anaerobic) conditions. Methane accounts for approximately 14% of all anthropogenic emissions of greenhouse gases worldwide (based on carbon dioxide equivalent); most of this CH_4 comes from agriculture (manures) and energy supply (Rogner, H. et al., International Panel on Climate Change, 2007). Nitrous oxide accounts for 8%; most of this N_2O comes from agriculture (use of N-rich fertilizers).

Excreta, wastewater, wastewater sludge, and biosolids are all possible sources of these greenhouse gases, depending on how they are managed. Management of municipal solid waste (MSW) and wastewater account for 2.8% of global emissions of greenhouse gases (carbon dioxide equivalents). This is a small amount compared to the energy sector, for example. Nonetheless, the wastewater and organic residuals management fields have begun taking concrete steps to reduce their "carbon footprint" (greenhouse gas emissions).

Energy use

In developed countries, the electricity used by a wastewater treatment facility is often a large portion of a municipality's energy use. In the USA, water and wastewater services account for 3% of electricity use. How excreta, wastewater, and wastewater sludge are managed can greatly affect this demand for energy and associated carbon dioxide emissions from fossil fuel use.

As noted in the report from Japan (Fujiki): "It is essential to shift away from a 'mass production, mass consumption, mass disposal' type of society toward a resource and energy recycling-oriented society… substances collected by sewerage have great potential as resources and energy that can be recycled and utilized… opening 'the way to resources' to help prevent global warming and achieve energy independence for wastewater treatment plants (WWTPs) by actively using the resource recovery and supply functions of sewerage, in addition to its usual functions, such as improvement of the water environment." This perspective has led to Japan's goal of 100% energy independence of WWTPs, which is to be achieved through improved efficiencies and energy savings at WWTPs, as well as maximizing energy recovery from wastewater sludge and other local organic "wastes" (e.g. food waste).

As discussed above, there is also increasing attention to generating heat and power from incinerators to offset fossil fuel use at wastewater treatment plants (see "Incineration"). Italy (Spinosa) reports a "higher interest toward energy reuse of residual sludge."

Controlling methane and nitrous oxide

As significant in addressing greenhouse gas emissions and global warming is the potential to manage excreta and wastewater sludge in ways that minimize the release of methane and nitrous oxide to the atmosphere while maximizing the extraction of renewable energy. This is one of fastest-growing developments in wastewater and wastewater sludge management today.

Excreta, septage, wastewater, and wastewater sludge can easily generate methane and nitrous oxide when they are left unmanaged and allowed to become anaerobic. This happens in slums and other densely populated areas of developing countries, where waste collects and decays in ditches and lagoons. It also happens in developed countries, especially where septage and wastewater lagoons are in use or there are large stockpiles of wastewater sludge.

Thus, improving access to sanitation and improving management of the collected excreta, wastewater, and wastewater sludge can substantially reduce greenhouse gas emissions.

Composting of these materials, when properly managed to keep them aerated, is one option. Direct land application involving little storage time is another. While use of biosolids on soil may lead to some generation of nitrous oxide, if it replaces use of chemical N fertilizer, it will likely reduce nitrous oxide emissions overall. (More research on nitrous oxide emissions is needed.)

Anaerobic digestion is a powerful answer to the problem of methane release from excreta and wastewater sludge. Many of the reports in this *Atlas* mention anaerobic digestion, which produces methane (digester gas, or "biogas") that can be captured and used as alternative fuel. In South Africa (Snyman) and Bulgaria (Paskalev), this is the most common form of wastewater sludge treatment. Los Angeles, California, USA (Lee) has been digesting wastewater sludge and utilizing the resulting methane for 40 years and plans to generate *in situ* underground methane by injecting wastewater sludge deep into fractured rock beneath its Terminal Island wastewater treatment plant.

Jeyaseelan reported in the 1996 *Global Atlas of Wastewater Sludge and Biosolids Use and Disposal* that, in Singapore: "On average, 40% of the power cost is met by biogas production." The wastewater treatment facility at Denver, Colorado, USA (Stefonick and Hull) produces 38% of its electricity with its own digester gas. In Bogota, Colombia (Campos), the anaerobic digesters are heated by combustion of the methane they produce. Digestion is also used in Japan, for example at Yokohama (Kawai). Rantanen reports that most larger cities in Finland anaerobically digest their sludge, and in Italy (Spinosa) 70% of wastewater treatment plants do so.

In addition to reducing methane release to the atmosphere and creating alternative fuel, anaerobic digestion has other benefits: it reduces the volume of excreta or wastewater sludge dramatically – by as much as 50% – and reduces pathogens. In Iran (Ghaheri), where about 40% of the population is served by effective wastewater treatment plants, the most common disposition for wastewater sludge is anaerobic digestion followed by land application in agriculture. Anaerobic digestion is also the sludge treatment used in the second-largest city in Namibia, Walvis Bay (Burger), where the resulting biosolids are bagged and used as soil amendment on city lands.

While anaerobic digesters are costly, and only larger, developed cities may be able to afford them, there is a great deal of effort and attention toward making them more cost-efficient. Systems for developing countries are being investigated. And a growing trend is to use them for treatment of other wastes as well. Grilc reports that in Slovenia, digester gas production is being maximized by adding food waste and separated organics from municipal solid waste. Norway (Blytt) reports similar co-digestion and increased methane production and use.

Growing energy crops with biosolids

Another recent and growing trend is the use of biosolids as fertilizer for energy crops. In developed countries especially, more and more agricultural lands are being used to grow corn, canola, reeds, *Miscanthius* (zebra grass), and other crops that are processed into alternative fuels. Part of the lure of using biosolids to grow energy crops is that this use is outside of the food chain, which can be a benefit in terms of public perception. In addition, by using local biosolids instead of transported and energy-consumptive chemical fertilizers, less energy is used for production of the fuel crop, helping to ensure a net positive energy outcome once the crop is grown, harvested, and converted to fuel.

Carbon sequestration

As attention to climate change and mitigation of greenhouse gas emissions continues to increase, scientists are recognizing additional benefits of biosolids applications to soils. These benefits are small in comparison to all anthropogenic greenhouse gas emissions, but they are significant.

Excreta, wastewater, wastewater sludge, and biosolids contain biogenic carbon (C) – carbon that is part of the pool of carbon constantly cycling through the biosphere and atmosphere. This C, when it becomes carbon dioxide, is not considered part of the human-caused emissions of carbon dioxide to the atmosphere. However, if some of this C can be kept from forming carbon dioxide, it can be counted as a reduction in human-caused greenhouse gas emissions. Applying biosolids to soils sequesters some C; how much and for how long depends on the particular biosolids material, soil conditions, weather, and other local factors. Soil scientists and the International Panel on Climate Change recognize that over the past few centuries (especially the most recent one), agricultural soils have lost more than half of their organic matter – their carbon. Returning carbon in the form of biosolids, animal manures, and composts will improve soil quality and crops while reducing carbon in the atmosphere. This fact is being recognized in marketplaces, where, for example, demonstrated lasting increases in soil carbon will be able to qualify as a "product" – a carbon offset – that can be sold on the Chicago Climate Exchange (CCX). Additional benefits are sequestration in the biomass growing in biosolids-amended soils and the potential to produce bioenergy crops that are harvested and used to offset fossil fuels.

"Beneficial uses of biosolids hold great potential as a significant component of activities and technologies to reduce GHG emissions and sequester atmospheric carbon. Biosolids have been used in forest fertilization, reforestation and afforestation to facilitate biomass production and soil development – two mechanisms for immediate carbon sequestration. As a fertilizer alternative, biosolids use reduces dependencies on chemical fertilizers derived from fossil fuels or from geological sources. Recent research has provided evidence that biosolids can be used as a component of fabricated soils that reduce fugitive methane emissions from closed landfills. Furthermore, beneficial use of biosolids precludes their disposal in landfills or incineration; both of these management options are sources of GHG and air pollutant emissions."

– Ellison and Jefferson, in the report from Canada, below

Management structures

In developed countries, centralized wastewater treatment systems began to be built in the 19th century. For example, the Sanitary District of Chicago – now the Metropolitan Water Reclamation District of Greater Chicago (Levy) – formed in 1889. In Yokohama, Japan (Kawai), sewer construction began in the 1870s after a major cholera outbreak. Nakajima reports that Tokyo's first wastewater treatment plant began operations in 1922. The smaller Sapporo, Japan (Namioka) began constructing its sewerage system in 1926.

Sanitation has always been a public function conducted mostly by governments. Today, around the globe, it is still mostly government agencies that construct and operate wastewater collection and treatment systems. However, private companies are contracted to conduct operations in many places, and all countries have significant commercial enterprises built around collecting excreta and septage and managing wastewater sludge and biosolids. For example, in Italy (Spinosa), it is mostly private companies and markets that manage biosolids (an exception is Puglia). In Vienna, Austria (Kroiss), the incineration plant "is operated by a mainly publicly owned private company responsible also for waste incineration and district heating."

Managing excreta, wastewater sludge, and biosolids in ways that protect public health and the environment require diverse knowledge and skills. It also requires strong organizations capable of operating facilities and systems continually, with a high degree of accuracy and quality control. In developed countries, a complex system of public agencies, private companies, equipment vendors, consulting scientists and engineers, operators, and supporting professional and educational organizations make this possible. Advancing this organizational and human capacity in developing countries is one of the challenges on the path to increasing adequate sanitation and proper fecal sludge and wastewater sludge management.

As described in the reports in this *Atlas* from countries around the world, there are two basic systems being used to manage excreta. In developing countries, latrines and pits contain the waste and it is transported to use or disposal sites, without the use of water, as a semi-solid material. In developed countries, most management involves conveying wastes to treatment sites (wastewater treatment facilities, lagoons, or septic tanks) using water; final disposition of treated wastewater sludge is mostly done using trucks and other machinery to transport materials to use and disposal sites. As discussed above, the options for final use or disposal are limited to landfillling, incineration, and recycling to soils. But, within these three categories, there are an ever-increasing variety of possibilities, and wastewater sludge management involves a significant cost (Table 5).

Table 5. Estimated percentage of total wastewater costs required for wastewater sludge management

Country or City	Estimated percentage of total wastewater treatment costs attributable to wastewater sludge treatment and management
Austria	45%
Bulgaria	20%
Canada: Greater Moncton	50%
Canada: Ontario	50%
Canada: Montréal, Québec	45% (operations & maintenance only)
Canada: British Columbia	30%
Canada: Alberta	18%
Czech Republic	57% (operations & maintenance only)
China	40%
Columbia	3%
England	18%
Japan: Tokyo	36%
Norway	50% (20% estimated in 1996 Atlas)
Russian Federation	24%
Slovakia	40%
Turkey	45%
USA: Milwaukee, WI	57% (operations & maintenance only)

For example, Italy (Spinosa) discusses co-management of wastewater sludge with municipal solid wastes (MSW) to overcome problems of handling sludge and MSW separately – especially co-composting. Three million tons of co-compost was produced in Italy in 2005 from 70% source-separated organics and green waste, 16% sludge, and 15% other food industry organic residuals. Co-incineration is another possibility. Spinosa notes that Sesto San Giovanni co-incinerates MSW and wastewater sludge in a self-sustaining burning process that produces 22,000 MWh/y of electricity.

The difficulty faced by co-management of sludge with other wastes is the common separation in regulatory structures between water and solid waste. But, just as nutrient management is integrating all types of fertilizers and manures and biosolids use on farms, integrated waste management programs are bringing together wastewater sludge and similar organic wastes in cooperative use and disposal scenarios.

The various country, state/province, and city reports in the chapters below describe additional developments in the management of excreta, wastewater sludge, and biosolids.

Legal matters and enforcement

Regulatory structures

In many countries, the management of excreta and wastewater sludge is overseen by national or state/provincial water quality control regulations. This stems from the fact that unmanaged waste moves with rainwater and runoff to surface and groundwaters that serve as sources of drinking water. To maintain potable water supplies, pollution has to be kept out of natural water bodies. Thus, water quality is the focus.

In developing countries, like Senegal (Ba), the Ministry in charge of water is also in charge of sanitation. This Ministry coordinates work on drinking water supplies and oversees the Senagalese National Office of Sanitation, which manages the country's excreta and wastewater sludge, including working with municipalities to install and empty latrines.

The level of government involved in regulating excreta and wastewater sludge varies from country to country. In Australia and Canada, the states, provinces, and territories operate somewhat independently of each other, and environmental regulations tend to be strongest and most restrictive at the state or provincial level. The challenge in these two countries (and others with similar structures) is a myriad of differing regulatory standards. As Gale notes regarding Australia, these differences "cause confusion and uncertainty to the general community."

Countries in the European Union (Matthews) have another level of legal and regulatory oversight – that imposed by EU directives. Directives provide minimum standards that are to be formally adopted in the laws and regulations of all member countries. Thus, as countries join the EU, they are forced to update their environmental standards and practices in a relatively short time. This has resulted in many new wastewater treatment facilities being built in some of the eastern European countries and Turkey (which is not yet a member of the EU) – with a resultant dramatic increase in wastewater sludge production.

In many developed countries, government agencies have also created guidance, which supplements regulations. Such guidance provides details on how excreta, wastewater sludge, and biosolids are to be managed and helps ensure current best management practices are used. Other organizations, such as non-governmental organizations like the National Biosolids Partnership in the USA and the Sustainable Organic Resources Partnership (SORP), have furthered the concept of best management practices and going beyond regulations; they encourage developing biosolids management programs that are "safe, sustainable, trusted, and welcome" (in the words of Peter Matthews, one of the founders of SORP).

While centralized or state/provincial governments tend to be the ones regulating and setting standards, almost everywhere the responsibility for performing the work of managing excreta and wastewater sludge falls to local communities. In the first biosolids *Atlas* (1996), Matthews emphasized this: management should be a local decision to meet local needs and the local environment. In Austria (Kroiss), the responsibility is local, but it is common for "communities to create regional authorities that take over this responsibility." Regional solutions can provide significant cost-efficiency benefits since it is far less expensive to build one larger facility for treatment of wastewater sludge than it is to build several smaller ones. Shared, regional wastewater sludge and other integrated organic residuals management programs are likely to increase in the future because they can be more sustainable.

However, municipalities need to have options available from which to choose – and the most resilient and reliable wastewater sludge programs tend to be in countries, states, and provinces where laws and regulations help maintain several environmentally sound options (see Table 15, below).

Many of the reports below include discussions of how local wastewater treatment facility managers decide how to manage their local wastewater sludge.

For example, China (He) reports that "the land application is the favored option," but "the potential toxic elements in sludge are of most concern." Landfilling is fairly common, "however, there is still a shortage of special landfill for sludge …most sludge is dumped or applied into simple landfill sites without strict operational requirements." So the existing infrastructure impacts local decisions about sludge management. He continues:

"The major points of concern in decision-making are the transportation cost, toxic elements in sludge and landfill capacity. Furthermore, the efficiency and cost of dewatering and drying are important for each disposal option.

In addition to the factors mentioned by He, there are several others mentioned by authors in the reports below. A very important one is regulations. Austria (Kroiss) and others begin their discussions of how the *Atlas* benchmark wastewater sludge would be used or disposed by a local utility by noting that its heavy metal content is too high for some regulatory standard, thus precluding its use in some forms of agriculture. In Slovenia (Grilc), the regulatory limits for heavy metals are so restrictive that they encourage exporting of wastewater sludges to other countries for incineration, despite the considerable cost. Regulations guide many decisions.

Enforcement

Having regulations in place is important, but how they are viewed by the public and whether they are followed (enforcement) is what counts. In parts of the developed world, public confidence in wastewater sludge management regulations and enforcement is sometimes lacking (e.g. see Lee regarding Los Angeles, CA, USA and Ellison and Jefferson regarding Canada, below). Enforcement – which includes educating key stakeholders and the public – is also an issue in many developing countries. As Ba notes, in Senegal "real problems are encountered when it comes to enforcement and making people respect these laws and regulations."

Enforcement requires a certain level of organizational and technical complexity. In Brazil, Andreoli et al. note that "one of the greatest difficulties found by the sanitation companies is related to the verification of the sludge sanitation concerning the presence of specific viruses

"Due to this demand, there is a great need of integration for technical and operational cooperation among companies, institutions and public administration involved in the process and the support from the farmers that will receive the sludge. Maintenance and reliability of defined processes are extremely important in order to reinforce the credibility in new[ly] implemented programs. This way, the environmental education has essential importance to the good development of this kind of programs and effectively promotes cultural and behavioral changes.

In this context, it should be emphasized that there is a great need for the changes in the cultural behavior of farmers from small and big properties, authorities, unions, so the access to information can make it possible to give new information to these participants and develop the possibility of constructive discussion about the real possibilities of this alternative. Another important cultural change is about the way people perceive the sludge disposition. Whereas it should be seen as an advantage as a new product, it is usually perceived as a problem that people want to get rid of."

– Note Andreoli et al.

and organic micro-pollutants. These kinds of analysis are not performed by most of the commercial laboratories, being restricted to some types of specific research in universities."

The fact is, the process of recycling biosolids to soils requires the integration of many people and actions, including wastewater sludge generation, processing, transport, and application to soils. These steps involve sanitation companies, rural production and technical assistance institutes, environmental control companies, farmers, equipment manufacturers and suppliers, and others.

Other forms of wastewater sludge management do not require the interactions of as many parties. Most incinerators that burn wastewater sludge are run by wastewater treatment agencies or companies. Landfills are run by people knowledgeable and familiar with waste management. In these situations, strong regulatory structures and enforcement are as important, but are easier to implement, because fewer people must be educated, involved, and overseen.

Policy development

Much research on wastewater sludge use and disposal has been conducted in the EU and USA. These countries have developed advanced analyses of the risks and benefits of the different use and disposal options. Many other countries have built their understanding and policies from this foundation of knowledge and experience, but integrate local needs and conditions into their policies, laws, and regulations.

In general, the USA has adopted the concept of risk assessment in its environmental regulations. The federal wastewater sludge regulations (40 CFR Part 503) are based on an extensive risk assessment completed in the early 1990s.

In contrast, the EU has adopted a precautionary approach or a no-net-degradation approach in some of its environmental policies and applies. Because of this, for example, the EU is well ahead of the USA in researching and phasing out chemicals of concern in personal care and commercial products, such as certain PDBEs (flame retardants). These actions are partly driven by the interest in protecting the quality of biosolids recycled to soils.

Despite these broader environmental policy differences, the USA and EU have created similar wastewater sludge regulations. The EU's central initiative on wastewater sludge management is the 1986 Directive for the Use of Sewage Sludge in Agriculture (which has seen additional development over the past twenty years). It and the USA federal regulations both address pathogen reduction, the potential for accumulation of persistent pollutants in soils (heavy metals and persistent chemicals), and application of appropriate amounts of nutrients. One notable difference is that the EU directive generally limits rates of applications of biosolids to lower amounts than are allowed in the USA.

Many EU countries have developed policies and regulatory standards that are even more strict than the Directive. Indeed, it is a phenomenon of regulation development that two different groups can be given the same data on risks but end up with significantly different regulatory results. The difference is a consequence of public perceptions, social and political conditions, and differing risk management approaches (precautionary principle versus risk/ benefit analysis).

When setting policies regarding excreta and wastewater sludge management, comparative risk analysis of the options is valuable. Biosolids recycling to soils, incineration, and landfill disposal all present risks and benefits. Precluding one option will result in environmental and public health impacts from another option. This is because, as noted previously, there is no option to not have significant volumes of excreta and/or wastewater sludge to manage. It exists.

Norway (Blytt), a non-EU European country has gone the furthest in establishing both a strong, integrated policy of recycling biosolids to soils, as well as setting tough standards. The development of Norway's policy and some details of its program is representative of an advanced and stringent regulatory scheme:

- In last part of the nineties, the policy to recycle organic waste increased, along with requirements to remove organic waste from landfills, in order to reduce emission of methane and leachate. Several municipalities started to source separate kitchen waste for making compost. The ministries found it necessary to harmonize the parallel regulations for different types of recycled organic waste. In 2003 a new joint regulation was initiated covering all organic materials spread on land derived from, i.e., farm waste, food processing waste, organic household wastes, garden waste and sludge. It was also believed that to elevate and standardize waste such as sludge would stimulate the sludge treatment plants regarding quality control and, sludge would be more acknowledged in the market. *The administration of the new regulation, "Regulation on Fertilizers Materials of Organic Origin", is led by the Ministry of Agriculture and Food in cooperation with the Ministry of Environment and Ministry of Health.* The regulation sets the following major requirements for organically derived fertilizers in general, with a few special requirements for sludge:
- All producers have to implement a quality assurance system.
- Quality criteria of the products include standards for heavy metal content, pathogens, weeds and impurities, in addition to a more general requirement of product stability (linked to odour emissions). There is a requirement for taking reasonable actions to limit and prevent organic micro-pollutants that may cause harm to health or the environment.
- Requirements on product registration and labelling before placement on the market

- Special crop restrictions for sludge, including a prohibition on growing vegetables, potatoes, fruit and berries for three years, and on spreading sludge on grassland.
- Requirements for storage facilities before use. Cannot be spread on frozen soil – no later than November and not before 15. February. Sludge has to be mixed into the soil (ploughing) within 18 hours after application.
- Beside the limit values for heavy metals, the hygienic requirements are: no *Salmonella sp.* in 50 grams and no viable helminth ova. and less than 2,500 fecal coliforms per gram dry solids.

This is a costly approach, and, ultimately, the Norwegian public, consumers, and sewer users pay a higher price for this level of environmental protection. As one of the wealthiest nations, Norway can afford this precautionary approach. And it has managed to create this very stringent regulatory program *and* meet its goal of recycling almost all of its wastewater sludges to soils.

Regulatory structures in other countries, which may not have the same level of resources to put towards wastewater sludge management, are less precautionary. Balancing strong regulations and enforcement with what is practical and achievable is the challenge of regulating. Snyman has pointed out that in South Africa, an initial set of biosolids management regulations that were consistent with some of the stricter regulations in Europe made management of wastewater sludge in South Africa nearly impossible. Newer, less stringent regulations are now helping move that country's wastewater sludge management programs forward toward higher levels of recycling and greater sustainability.

Eventually, as resources allow, all countries can achieve the kind of high regulatory standards that Norway has, if their citizens decide the marginal improvements from a risk-based approach to a precautionary approach are worth the extra cost. But, initially, most countries have to find ways to steadily reduce risks and improve environmental protection over time. As in South Africa, it is difficult to jump too quickly to the most stringent regulatory scheme.

Policy should reflect priorities, and regulations should reflect policy and create incentives for achieving particular goals. In many jurisdictions (national and state/provincial), recycling of "wastes" – including biosolids – is a stated priority, but the regulatory structures end up leading away from this goal. Developed and developing countries will continue to wrestle with this challenge as they update and improve their excreta and wastewater sludge management policies and regulations.

The need for continual public consultation

In each community around the world, the management of excreta, wastewater sludge, and biosolids happens in a cultural, political, and social context.

A most basic element of that context is fecal aversion – an inherent human trait, demonstrated, for example, by research that shows that the smells associated with human fecal matter are the most repulsive. As the report from New Zealand (Bradley) notes, "faecal phobia by many regional councils, and their disregard for the science upon which the 'Guidelines for Safe Application of Biosolids to Land in New Zealand' are based has meant the goal of 95% beneficial reuse of biosolids has not been realized in New Zealand."

controlling potential risks to soils and crops by limiting application rates

Using biosolids on soils involves a balance between supplying the soil and crops with vital nutrients and organic matter and taking advantage of the assimilative capacity of the soil, so that trace amounts of chemicals or heavy metals do not cause harm. Limiting how much biosolids are applied helps achieve this balance.

One common and significant restriction imposed on biosolids application to soils is limiting the rate of application in order to limit accumulation of potentially toxic substances, such as heavy metals and toxic chemicals. States and countries around the globe have adopted such restrictions in regulations or guidance. Restricting the levels of heavy metals and some organic chemicals in biosolids or receiving soils and restricting how much biosolids are applied at any one time or during any time period (one or several years), reduces any potential for dramatic changes in soil chemistry that could disrupt the soil ecosystem or harm crops, aquatic systems, or animal or human health.

Thus, in South Africa, in 1996, the amount of biosolids that could be applied depended on the concentration of heavy metals in the biosolids: a higher quality low-metals biosolids could be applied at a higher rate. The European Union (Matthews) 1986 directive establishes "maximum concentrations in the soil… and maximum concentrations in the sludge… or maximum rates of addition expressed as an annual average over a 10-year period." U. S. EPA imposes similar national standards, including use of the "agronomic rate" of application; that is, only as much nitrogen (or, in some cases, phosphorus) as the crop needs on an annual basis. Typical agronomic application rates in the USA are 3-10 dry tonnes biosolids/hectare/year, depending on the amount of nitrogen required by the specific crop and the amount of nitrogen supplied by other sources, such as crop residues and animal manures.

The reports from several countries, below, discuss maximum limits on application rates; some of these are in addition to an agronomic rate restriction; here are some examples:

- Jordan: 6 dry tonnes biosolids/hectare/year
- Ontario, Canada: 22 dry tonnes biosolids/hectare over 10 years
- China: 30 dry tonnes biosolids/hectare/10 years
- Italy: a maximum of 15 dry tonnes biosolids/hectare/3 years – and less on some soils
- Norway: varies based on soil type, but generally only 1 application/10 year

People prefer to ignore what happens to excreta after it is flushed or in the latrine – and they are uncomfortable if it is brought to their attention. Recycling biosolids to soils involves bringing back to people's attention something associated with human excreta. This often results in public dismay or outrage.

Those who manage excreta, wastewater, and biosolids have always had a lot to explain about their jobs, why they do what they do, and how it is not as bad as people think it must be. Sanitation workers work on the front lines of environmental and public health protection, but they don't usually receive much acclaim; in fact, they are hardly noticed.

These facts of human nature mean that sanitation is often ignored socially and politically. This means that public discourse about new sanitation infrastructure or ways to manage wastewater sludge is stymied.

To address this social and political reality, those managing excreta, wastewater sludge, and biosolids have learned the importance of communications and regular public outreach. Individuals may not want to learn more about wastewater and biosolids management, but the public needs to know about it, so they help guide appropriate policy and regulation – and so they provide financial support for infrastructure and operations.

Many of the most successful biosolids recycling programs in developed countries have gotten where they are because of regular, proactive communications and consultations with the public. The goal of such efforts is not only to help people reconsider their innate aversion to biosolids, but also for the biosolids manager to better understand the particular concerns of people living near biosolids management operations and adapt best management practices to address those concerns. Ultimately, in developed countries, wastewater and biosolids management are public functions, conducted in the public interest. For any program to be sustainable, it must become trusted and welcome by the public.

Excellent communications and working with the public are challenging, but necessary, parts of any excreta, wastewater sludge, or biosolids management program.

There are times, however, when conflicts develop, and, in some areas, the legal system plays a significant role in helping define biosolids management policy. For example, the report from Los Angeles, California, USA (Lee) describes an ongoing precedent-setting legal battle between large wastewater treatment districts in the southern part of the state and the rural, agricultural Kern County, where voters tried to ban the recycling of out-of-county biosolids. So far, the courts have rejected the ban on biosolids use, but appeals continue. The uncertainty created by this situation forced the city to develop other, more expensive contracted outlets for its biosolids.

Today, in many developed countries, this kind of uncertainty created by a public upset about a few biosolids management programs is challenging the concept of biosolids recycling to soils. Communications and consultations with the local public will be ever more important if diverse options for biosolids management – including land application – are to remain available.

OVERVIEW OF PRACTICES

What would happen to the benchmark sludge?

Many of the authors of the reports in this *Atlas* were asked the following (in the words of Peter Matthews, editor of the first global *Atlas* in 1996): "if you had this sludge… to dispose of with your local laws, political prejudices, geography, economy, opportunity and so on – how would you do it? The simple concept would be, in effect: if a new city with a wastewater treatment plant of 100,000 p.e. [person equivalents] was built in your region, how would you cope with the problem of sludge disposal?"

The benchmark sludge used in the 1996 *Atlas* and in this compendium is the same. It is described as untreated and having mid-range levels of contaminants (heavy metals).

The authors of about a dozen of the reports in this current *Atlas* responded to the questions about the benchmark wastewater sludge and how it would likely be managed in their country or province (Table 6).

In all cases, the benchmark sludge could not be used as a fertilizer or soil amendment if it had not been first stabilized to reduce pathogens and vector attraction. In some of the jurisdictions reporting, biosolids cannot be used on food crops. In others (e.g. Norway), the levels of heavy metals in the benchmark sludge are too high to allow for use on food crops. However, in 7 of 12 jurisdictions, wastewater sludge management programs would most likely stabilize the benchmark sludge and apply it as a soil amendment in construction of parks, golf courses, construction sites, etc., or to agricultural lands or forest areas. In short, the benchmark sludge can be used on soils in those places where that is done. In Bulgaria, China, Japan, and the Netherlands, most wastewater sludge is disposed of in landfills or burned in incinerators – and those would be the likely fate of the benchmark sludge in those countries.

Table 6. How the benchmark sludge would be managed

Country/ Jurisdiction	Likely use or disposal of benchmark sludge: Land ap ag	Other use on soils	Incineration	Landfill	Notes
Bulgaria				X	Sludge first by anaerobic digestion, then placed in a partitioned sludge-only landfill cell.
Canada – Greater Moncton Sewerage Commission (GMSC)		X Compost			Sludge composted to make a 'Class A' product for unrestricted use
Canada – Québec				X	Most sludge is incinerated, but from the benchmark size city, more sludge is landfilled and some is land applied. The benchmark meets the "contaminant 2" regulatory category and could be land applied, with restrictions, after stabilization, most likely by composting. Limited to 22 dt/ha/5 years.
Canada – British Columbia		X			After treatment for pathogen and vector attraction reduction, use in land reclamation is most likely.
China	X				Application to crops other than vegetable and pasture/forage; must be stabilized by composting or digestion and dewatering.

	Likely use or disposal of bench-mark sludge				
Country/ Jurisdiction	**Land ap ag**	**Other use on soils**	**Incin-era-tion**	**Land-fill**	**Notes**
China – Hong Kong				X	Sludge must be dewatered first.
England	X				Would be managed as part of a regional sludge operation; sludge would be stabilized most likely by anaerobic digestion and must meet other management restrictions; a site permit is not required, but regulations, Code of Good Practice, and Safe Sludge Matrix must be followed to avoid liability.
Japan – Tokyo			X		After thickening (digestion) and dewatering; the incineration reduces the sludge volume to one-hundredth. The ash is mostly used in construction materials (56% for cement, 33% for lightweight aggregate).
Netherlands			X		Sludge is stabilized and dewatered by composting first, then used as a biofuel at power stations.
Norway		X			Could not be land applied on arable land because the levels of lead and zinc are too high; would likely be used as part of a soil blend for use on green areas (golf course, construction sites, roadsides, parks) – but only after stabilization and if stabilization did not increase lead above 200 mg/kg.
Russian Federation		X			Application to plantation forest land is most likely (does not meet contaminant standards for agricultural use). "Sludge could be used after pathogen reduction, composting or in mixture with sand and peat; the typical application rate is 60-80 t DS/ha."
South Africa	X				Would be classified as Class C3a if it is left as is, meaning it would likely be dewatered and incinerated. However, it is more likely to be stabilized by anaerobic digestion, making it a Class C1a or B1a biosolids that would be used in agriculture, with restrictions. Could not be put to general public use, as that requires Class A1a.

Regional differences, similarities, and trends

Excreta and wastewater sludge quantities

There is no avoiding the fact that humans produce excreta – feces and urine – that require some form of containment and management in order to protect public health.

In the lowest-income countries reporting in this *Atlas*, there are few estimates of the quantities of excreta, septage, and wastewater sludge produced. More developed countries have begun to generate estimates and collect data on wastewater sludge produced and used or disposed. Table 7 is a compilation of some of this data from the reports in this *Atlas*.

Table 7. Estimated sewage sludge production and populations of reporting countries

Country	Estimated Sewage Sludge Production (dry metric tons)	Population (from http://www.infoplease.com/ipa/A0004379.html)
Brazil	372	188,078,000
China	2,966,000	1,313,974,000
Turkey	580	70,414,000
Slovakia	55	5,439,000
Hungary	120	9,981,000
Japan	2,000,000	127,464,000
Canada	550	33,100,000
Italy	1,000,000	58,134,000
Norway	86,5	4,611,000
Czech Republic	200	10,235,000
USA	6,514,000	298,444,000
Portugal	236,7	10,606,000
Germany	2,000,000	82,422,000
United Kingdom	1,500,000	60,609,000
Slovenia	57	2,010,000
Finland	150	5,231,000
Netherlands	1,500,000	16,491,000

This rough data highlights an important fact: the higher-income countries that have the most comprehensive infrastructure and treatment technologies (e.g. secondary and tertiary treatments) produce the largest masses of wastewater sludge per person. The middle-income countries included in Table 7, which have less-developed wastewater treatment infrastructure and collect and treat wastewater from lower percentages of their populations, produce far less wastewater sludge per person on a national level.

Looking ahead, this means steady increases in wastewater sludge production are likely in many parts of the world in the years to come (see Table 15, below).

The inevitable progression of sanitation and wastewater sludge management

There is, naturally, a strong correlation between the wealth of a nation and the development of its sanitation, wastewater, and wastewater sludge management systems. This relationship is expressed using Gross Domestic Product per capita (GDP/capita) as a measure of wealth (Table 8). Increased wealth affords adequate sanitation for all citizens, followed by a shifting of focus from purely public health concerns to environmental concerns. Regulation and management systems become increasingly complex and target reductions of increasingly smaller risks.

Table 8. Stages of excreta and wastewater infrastructure development

Lack of basic sanitation facilities for majority of population; excreta disposed in rudimentary latrines, ditches, along roads, or in environment. Focus is on individuals avoiding their waste.		Human waste containment and collection systems developing. Focus is on community public health: protecting drinking water and avoiding spread of disease. Treatment of collected waste is minimal to none.		Treatment systems (mostly for wastewater; but also dry excreta treatments) are developing to manage contained and collected human waste. Regulatory systems focus on public health; protecting environment is secondary.		Effective wastewater treatment (and dry excreta management) systems are in place. Focus is on effluent quality to protect public health and the environment. Sewage sludge & biosolids quality is under examination; sustainability of programs is becoming a priority. Regulatory structures often at two or more levels of government.
Urban/ Suburban/ Peri-urban	**Rural**	**Urban/ Suburban/ Peri-urban**	**Rural**	**Urban/ Suburban/ Peri-urban**	**Rural**	**Urban/ Suburban/ Peri-urban & Rural**
						Australia (100%)
						Austria (100%)
					Bulgaria (96%)	Bulgaria (99%)
	Brazil (37%)	Brazil (84%)	Brazil	Brazil		
Burkina Faso (41%)	Burkina Faso (6%)	Burkina Faso				
Cameroon (58%)	Cameroon (42%)	Cameroon				
						Canada
			China (59%)	China (74%)	China	China
	Colombia (58%)	Colombia (85%)	Colombia	Colombia (Bogota)		
Côte D'Ivoire (38%)	Côte D'Ivoire (12%)	Côte D'Ivoire				
						Czech Republic (99%)
						England (UK)
Ethiopia (27%)	Ethiopia (8%)	Ethiopia				
						Finland (100%)
						Germany (100%)
						Hungary (100%)
				Iran (86%)	Iran (83%)	Iran
						Italy
						Japan (100)
				Jordan (88%)	Jordan (71%)	Jordan
Mali (59%)	Mali (39%)	Mali (Bamako only)				
			Mexico (48%)	Mexico (91%)	Mexico (48%)	Mexico
Mozambique (53%)	Mozambique (19%)	Mozambique (Maputo partially)				
	Namibia (18%)	Namibia (66%)		Namibia (Walvis Bay)		
						Netherlands (100%)
Nigeria (35%)	Nigeria (25%)	Nigeria (35%)				
						New Zealand
						Norway
						Portugal (99%)
				Russia (93%)	Russia (70%)	Russia
Senegal (54%)	Senegal (9%)	Senegal (Dakar only)				
						Slovakia (100%)
						Slovenia
	South Africa (49%)	South Africa	South Africa	South Africa (66%)	South Africa (49%)	South Africa (some urban)
				Turkey (96%)	Turkey (72%)	Turkey
						United States (100%)

NOTE: Country name (% access to improved sanitation, per WHO 2006, except Iran data is from 2000)

The lowest-income countries

In sub-Saharan Africa and parts of Asia and Central and South America, basic sanitation is lacking for large numbers of people. Management of raw waste from waterless latrines or simple water-borne systems is needed. The driving issue is control of diseases transmitted by human waste and reduction in pollution of natural water bodies (rivers, lakes, oceans).

Reports from Africa included in this Atlas are from Burkina Faso, Cameroon, Côte D'Ivoire, Ethiopia, Mali, Mozambique, Namibia, Nigeria, Senegal, and South Africa. All of these countries have large numbers of people living in poverty or extreme poverty. In rankings of Gross Domestic Product per capita, most of these countries are near the bottom, in the range of 126th (Nigeria) to 173rd (Ethiopia). The reports from these countries focus on the need for basic sanitation infrastructure and services. The shared challenges include:

- large population increases in urban and peri-urban areas;
- obtaining adequate funding for waste collection and treatment infrastructure;
- figuring out how to place infrastructure in very densely populated areas such as slums;
- developing sustainable social and governance structures to manage excreta, septage, and wastewater sludge consistently;
- gaining adherence to environmental laws and regulations; and
- educating the public on best sanitation practices to protect public health and the environment.

These are the challenges that must be faced in order to meet the UN Millennium Development Goals target of halving, by 2015, the number of people living without access to adequate sanitation. Numerous international aid programs and non-governmental organizations, including UN Habitat and other UN agencies, are working in these countries to address the needs – and there are some examples of great progress. However, more international aid funding is needed if the MDG target is going to be reached.

The differences between the situation in many parts of Africa and that in North America, Europe, Japan, and Australasia are staggering. The most developed countries spend billions of dollars a year on wastewater and sludge management to achieve now-marginal improvements in water quality and environmental integrity, while millions in the poorest countries die because of lack of basic sanitation. Moving people out of poverty involves developing proper sanitation. And climbing the ladder of development leads to continual improvements in sanitation and public health. In this Year of Sanitation 2008, developed countries need to recognize and act on the fact that reducing poverty and improving sanitation helps reduce the risks of virulent pandemic diseases and social and political unrest that can affect them directly.

As noted in the report from Mozambique, only the capital city of Maputo has a sewage treatment plant that is even partially functioning; other treatment plants in other cities are not functional at all. In Maputo, the plant is in a flood-prone area, is connected to only an estimated 10% of the population, is poorly maintained, has no pathogen treatment, has no monitoring of effluent quality, and no sludge has been removed "since operation started." Meanwhile, "studies of Maputo Bay revealed that…levels of pathogens causing severe gastrointestinal infections have been increasing over the years…which entail significant socio-economic problems."

Cote D'Ivoire reports that "poverty, which was previously rural, has moved into the urban milieu with the phenomenon of the exodus from rural areas. This has resulted in a concentration of populations that exert great demand on social services." Efforts and studies were made in the 1970s and 1980s to address sanitation and drainage needs, but efforts stopped from 1987 to 1999, after the dissolution of SETU/DDA and the Fonds Nationale de l'Assainissement. In 1999, four cities had directors of sanitation: Abidjan, Bouaké, Yamoussoukro, Daoukro; this increased to 7 by 2002 (Daloa, Gagnoa, San Pédro). Abidjan now has a 2000+ km collection network and 51 "stations." But recent plans for sanitation have not been executed because of the socio-political instability and military situation in the country. A federal program to ensure 15-20 liters of safe potable water to rural citizens has reached only 50% of the villages, and water-borne diseases continue to be a significant problem. A new study has started investigating the coverage around the nation of appropriate sanitation. The plan is to build collection systems and treatment plants in most cities and develop on-site systems and latrines in most towns. Private enterprise is being encouraged to help make the necessary investments in the operations and maintenance of the larger wastewater treatment systems.

Similar low levels of access to basic sanitation are described in reports from other parts of Africa: 62% and 80% of the populations of Nigeria and Burkina Faso, respectively, have no access to sanitation. The report from Ethiopia estimates that almost ⅓ of the population defecate informally along roads and rivers and that, where minimal sanitation structures exist in the city, there are not enough trucks or other systems for moving the excreta to treatment or utilization. Still, some is used on crops, causing concerns about contamination of food and spread of disease.

Mali is also typical of the poor African countries. The percentage of the population with no access to sanitation is estimated to be 67% in urban areas and 91% in rural areas. In the capital of Bamako, there is some collection of waste, but no treatment. Wastewater is discharged directly into the Niger River. It costs about US$50 to have a truck clean out and transport excreta from latrines – but there is then no place for the material to be disposed of properly. The same is true for industries; for example, artisans that dye fiber produce an estimated 16,000 m^3 of wastewater per year that is discharged into ditches, streets, and waterways.

But improvements are evident. Information is being gathered by governments that helps better understand the sanitation needs and ways to address them. Data from the city of Harar, Ethiopia, shows that 74% of households have toilets, almost all of which are dry pit latrines; these data show some improvement since a 1994 survey. In Mali and elsewhere, ventilated improved pit latrines (VIPs) and Ecosans, are increasing in numbers – and aged urine and treated feces from the latter are beginning to be used as fertilizers. A new wastewater treatment plant is being built in an industrial zone in Bamako, Mali. The national government and NGOs are advancing projects, with the local assistance of community groups and families.

In Burkina Faso, waste treatment options are developing. Traditionally, individuals take care of their own latrines or other waste containment systems. Increasingly, community latrines are being created and managed by community groups. And some producers of larger quantities of wastewater, such as hotels, hospitals, and markets are developing septic systems or sewers connected to wastewater treatment facilities or lagoons.

Where there is less poverty, sanitation programs in Africa are doing far better.

Middle-income countries

Middle-income countries represented in this Atlas include several each from Africa (Namibia, South Africa), the Middle East (Iran, Jordan, Turkey), Asia (China, Russian Federation), and Latin America (Brazil, Colombia, Mexico). These countries' ranking in terms of GDP/capita range from 102nd (Jordan) to 52nd (Turkey). As is expected, the development of sanitation services and wastewater treatment infrastructure is greater here than in poorer countries. Collection and treatment systems serve many, but certainly not all, urban residents. Much of the wastewater treatment is at the preliminary or primary level, although secondary treatment is found in some urban areas (Figure 3). Many rural residents rely on on-site and simple sanitation technologies, but some still have limited or no access to adequate sanitation.

The report from Namibia focuses on the country's second largest city, Walvis Bay (population 60,000), and describes a functioning system of anaerobic digestion and drying beds that leaves a biosolids material that is bagged and applied to city parks, sports fields, and gardens.

In wealthier South Africa, 68th in ranking of GDP/capita (one of the highest in Africa), development has included significant wastewater treatment infrastructure in some of its urban areas. However, like much of the rest of Africa, informal settlements in peri-urban areas face significant challenges from lack of sanitation. The difference for South Africa is that its relative political and economic stability and higher-income has allowed for extensive government investments in sanitation.

Snyman describes efforts in eThekwini, South Africa, which has a population of 3 million, to "provide a basic package of sanitation and water in the form of urine diversion (UD) toilet and a 200 litre yard tank to all households outside of the waterborne sewage and unable to pay for water services." Nearly 60,000 had been installed by the end of 2007 – significant progress. But there are still many more households that await this improvement.

In the meantime, the municipality also spends $8.75 million "to empty the 100,000 existing pit latrines that required urgent emptying." But it will remain a significant challenge for the municipality to meet its goal of emptying all latrines every five years. Snyman notes that this high cost of latrine emptying is not sustainable, even for large municipalities. The ultimate objective is to connect at least peri-urban areas to the waterborne system, which will require more treatment capacity and wastewater sludge management.

While supplying basic sanitation to stem the spread of disease is the current focus in much of Africa, what happens with the collected excreta. septage, and sludge is the inevitable next challenge, as Snyman notes. "If space allows, the faecal sludge is buried on site. Where this is not feasible, the sludge is blended into the waterborne system, which completely overloaded the wastewater treatment plant in at least one case."

Just within Africa, from Ethiopia to South Africa, experience demonstrates that progress in development involves improved sanitation and the inevitable shift toward waterborne waste systems as the necessary norm in densely populated regions. As is happening in middle-income countries, this reliance on wastewater systems leads to more complex wastewater treatment infrastructure that produces wastewater sludge that must be managed. South Africa is a country in which we see, perhaps more than in any other, the full diversity and range of sanitation programs and progress – from essentially none to sophisticated modern urban systems that are facing the challenges of modern biosolids management (Table 8).

Table 9. Levels of wastewater treatment in some middle and, for comparison, higher-income countries

Country	% of population with no wastewater treatment	% of population with primary treatment only	% of population with secondary and greater treatment
Canada	~0%	10%	90%
China – Hong Kong	30% (preliminary treatment only)	53%	17%
Germany	~0%	6%	94% (including nutrient removal & tertiary purification)
Mexico	59% (ponds, advance anaerobic treatment)	41%	
Portugal	39%	19%	43% (24% have tertiary treatment too)
Turkey		9%	91% (up from 63% in 1994)

This inevitable trend of sanitation development, which goes hand in hand with overall development, holds promise for reducing disease and improving public health. But it also creates more wastewater sludge that must be managed. In middle-income countries, we are now witnessing the growth of this challenge: what to do with wastewater sludge?

China is one of the fastest-growing economies in the world, with a high rate of technological development. He reports a one-year increase in sewage production in the country's urban areas of 5.4%. Wastewater sludge management is overseen by national ministries, and new regulations were released in 2007 that set standards for the levels of contaminants in wastewater sludges and the options of use and disposal: "four types: land application, landfill, production of usable materials and incineration."

China, like other middle-income countries, is in the midst of updating and strengthening its wastewater sludge management program. By reviewing the scientific literature and experiences in more developed countries, China is leap-frogging to an advanced regulatory program that includes encouragements for biosolids recycling to soils, restrictions on use on food crops and grazing lands, limits on heavy metals and dioxins and furans reflective of those in the USA and EU, and concerns about persistent organic pollutants and endocrine disrupters.

Land application of biosolids in agricultural settings is the most common use or disposal in China. As in other middle-income countries, simple land application is affordable and is seen as preferable to landfill disposal, which is the other less expensive alternative. About incineration, He notes "the cost of sludge drying and incineration is the major factor influencing their application" (4% of China's wastewater sludge is disposed in this way). Landfilling is still an important outlet, but, as with other options, the regulations are tightening, and there is less random "dumping."

Russia shares many of the same challenges as China, except for the population pressures. Some of its wastewater treatment infrastructure is 50 years old or more, and Russia has considerable experience with wastewater sludge management. However, it too is strengthening its regulations and working to ensure proper management and best practices are in force. Gunter and Belyaeva note that heavy metals concentrations in Moscow area wastewater sludges (and others) do not create any issue with recycling the materials to soils. However, the lack of recycling to soils is due to the sludges' "non-market conditions and poor sanitary standards." Thus, in Russia, most wastewater sludge is placed in landfills, often with municipal solid waste, or long-term drying beds. Like China and other middle-income countries, the number and use of incinerators is limited; there are two in St. Petersburg.

In Brazil and Mexico, research is advancing the use of biosolids on land, and, in both countries, demonstration projects are showing the value and controllable risks of this method for managing wastewater solids. As is the case in China, new regulations have just been created or are being developed, and the standards included in these regulations are as comprehensive as many in more developed countries. For example, in Brazil, there are restrictions on slope (>5%), the kinds of crops biosolids can be used on, and the time of year when applications to land can be done, to avoid excessive runoff in the rainy season. Brazil's regulatory limits on concentrations of heavy metals are similar to those in the USA. Mexico's heavy metals standards, established in 2002, are the same as those in the USA, and it has set a goal for increasing the rate of biosolids recycling to soils.

However, in these Latin American countries, the obstacles are apparent; write Garcia et al.: "There is no data on the total amount of sludge treated in Mexico and most of the WWTPs have no sludge treatment systems. This is a worrying situation due to its potential to pollute water sources and soil. The reason for this situation is that due to the high cost that sludge treatment represents, some cities have already begun their own reuse projects."

Colombia (Campos) is at an earlier stage in the development of sanitation and wastewater treatment infrastructure than the other middle-income countries reporting in this *Atlas.* Only 5-10% of municipalities "carry out any type of wastewater treatment," reaching only 5% of the urban population, and "the infrastructure for wastewater treatment is still unreliable." Colombia is in the process of research and regulation development for management of wastewater sludges and biosolids recycling to soils, and Campos provides some details about the results of recent research on use of biosolids in agriculture.

The Middle Eastern countries have similar challenges. Jordan has nineteen wastewater treatment plants that store wastewater sludges in drying beds and then haul them to "dumping sites" or store them near the plants. The country has taken a first step toward building a wastewater sludge management and regulatory system: creating an analytical manual for testing of biosolids – a necessary part of gaining understanding of the materials to be managed and what regulatory controls may be necessary.

The report from Iran (Ghaheri) raises the important topic of *industrial* wastewater and sludges and their management. "There are many problems in our country in dealing with industrial wastes including hazardous wastes," writes Ghaheri. Municipal wastewater sludges, however, are not mixed with industrial wastes in Iran, and digestion, lagooning, composting, and landfilling are the most common routes of use and disposal. There is some use of wastewater sludges in agriculture.

In part because it is a candidate for EU accession, Turkey (Filibeli) is quickly advancing its wastewater and wastewater sludge management programs. Seventy percent of the population lives in urban areas; 37% of the population is connected to sewers. Of the wastewater that is treated, a third receives only primary treatment, while two-thirds is treated to the secondary or tertiary level. Like Russia and other middle-income countries, the potential for increasing recycling of biosolids is stymied by "deficiencies in practice in sludge stabilization, which is the most important part of sludge handling for many reasons such as the reduction of pathogens and odor emissions." Because of these challenges, and despite interest in increasing the rate of recycling to soils, most Turkish wastewater sludge – like that in other middle-income countries – is disposed of in landfills.

Higher-income countries

Unlike the case in low and middle-income countries, in higher-income countries, policies for wastewater sludge management have been refined over a decade or more. Policies, regulations, and best management practices are generally established at both the national and provincial or state level. Regulatory structures are relatively complex, and there is a high level of enforcement and compliance.

In these countries, wastewater treatment and wastewater sludge management are advanced and often technically complex. Infrastructure, some of which is quite old, is being upgraded and improved. The public commitment to wastewater treatment and its funding, while not always at an optimum level, are strong.

In much of Europe, Australasia, East Asia, and North America – and in urbanized areas in other regions – almost all excreta is waterborne, requiring collection and treatment either in local, onsite systems or community wastewater systems. The current driving issues are several: the further control of pathogens and the minimization of releases of excessive nutrients, elements, and chemicals to the environment. In these technologically advanced societies, with rapid global communications, the same issues are being explored everywhere:

- As scientists detect very small concentrations of chemicals in the environment, what does it mean? Wastewater and biosolids contain pharmaceuticals and personal care product (PPCP) chemicals, some of which are endocrine disrupters and some of which are antimicrobials. What, if any, are the significant impacts of these in the soil environment where biosolids are applied?
- What are the fates and impacts of persistent organic pollutants (POPs), such as PDBEs?
- Can more complex microbial risk assessment and other tools help better address some uncertainties about the effectiveness of traditional pathogen reduction treatments?
- How do the relatively high amounts of phosphorus (P) in biosolids – but lower bioavailability of biosolids P – affect agricultural soils and their environments over the long term?
- How can energy be most efficiently extracted from biosolids?
- What are the greenhouse gas impacts of differing methods of managing wastewater sludges?

These are the topics of current research in the most-developed countries. In these countries, biosolids are generally considered resources, and government policies generally encourage their use. Research and decades of experience in the use of biosolids on soils and for energy are the basis for current fine-tuning of practices. Refinements of traditional technologies and best management practices are shared around the globe. Scientists are finding more ways of digesting wastewater sludge, for example at thermophilic temperatures or a mixture of temperatures and/or with the sludge feed treated with one of several forms of lysing (cell disruption to enhance digestion efficiency and increase methane fuel production). Dewatering is becoming more efficient with new centrifuges, screw presses, electro-dewatering, or advanced solar drying technologies. And in the global trend toward energy efficiency, there is a rush to find ways to remove the water from wastewater sludge in an efficient enough way, so as to yield a net energy benefit when the wastewater sludge is burned in an incinerator. In some areas, water conservation activities (such as Watersense) are being developed to reduce the amount of water that has to be removed.

But these foci of wastewater sludge management professionals and regulators are not necessarily the foci of the general public. And, in these most-developed countries, the environmentally-aware public plays an increasing role in guiding wastewater sludge management policy and regulation. In the media and public, there are widespread concerns reported about traces of chemicals and heavy metals in the environment, about disease transmission and antibiotic resistance. That's what the public is talking about. These competing trends are the foundation on which debates about wastewater sludge management build.

There is a shared understanding worldwide of the problems with disposal in landfills and the "throw-away society." In the Czech Republic, Jenicek notes the "low social acceptance" of landfilling, and, there, land application and composting are the dominant ways of managing wastewater sludge. In Bulgaria (Paskalev), where landfilling has been dominant for decades, standards and regulatory structures for biosolids recycling to soils are now being developed.

The European Union has directed the phase-out of landfilling of organic wastes, mostly because of concerns about releases of the greenhouse gas methane. Thus, environmental regulators there (and throughout the world), supported by the public, seek to minimize reliance on landfills. As countries are able to afford alternatives and have effective regulatory controls in place, landfilling of wastewater sludge has been diminishing. Australia (Gale) reports that "landfill is not considered a beneficial use of biosolids and is not, or soon will not, be an acceptable option in any state or territory." Japan is also focused on avoiding landfilling of organic wastes. Wastewater sludge has become widely recognized as too valuable a resource to reject.

But while much of the public widely supports reducing landfilling of organic residuals like wastewater sludge, there are concerned publics in some developed countries who oppose the use of biosolids on soils. Switzerland, which reported in the first *Atlas* in 1996 that most of its biosolids were land applied on pastures and croplands, has since banned the use of biosolids on soils. The Netherlands has effectively done the same, as have two of nine states in Austria. In these cases, there is an overabundance of animal manures, and farmers and the public more easily accept manure recycling to soils. Incineration of wastewater sludge has become common in Switzerland and the Netherlands and is increasing elsewhere in the EU, driven by public dislike of landfilling and concerns about land application.

The public is forcing shifts. In the USA EPA report in this *Atlas*, Stevens states "sustainable management of residual material is in the public interest," and he goes on to emphasize the importance of the use of the nutrients and organic matter in biosolids for the long-term health of soils and crops. But Lee reports from Los Angeles, California, USA, that "the City has faced and overcome certain legal and regulatory challenges fueled by certain misperceptions regarding the safety of and benefits of biosolids recycling." Negative public perceptions of biosolids use on land, often triggered by malodors released during land application operations, are becoming deeply engrained in some places.

Thus, about Ontario, Canada, Rupke writes:

> *One of the factors that are often critical in the public process and decision making is the political acceptability of each option. While almost all options are legally available, in some areas of the province they may not be considered acceptable by part of the local population. In some cities incineration is not acceptable, even though it may be preferable from an environmental and economic standpoint. In other areas biosolids application to land is considered unacceptable, even though there is amply suitable farmland close by. These considerations are often driven by vocal local opposition, based on fear of environmental impact, or odours. This has resulted in large cities having to haul biosolids over 500 km to find available farmland or landfills. The concern over odours at rural application sites has led to a preference for liquid application by direct injection, or surface application followed by immediate incorporation.*

Often the best environmental and most energy-efficient solution for wastewater sludge management is not supported by the public – or at least not at first. Professionals who manage wastewater sludge are increasingly aware of the need for public consultation as wastewater sludge management decisions are being made. As wastewater sludge policies, regulations, and management programs are developed, the public should be involved, to ensure their support once the program begins operations. Too often, expensive biosolids recycling or thermal processing programs have been designed and built by engineers with little public consultation, only to have the public put pressure on regulators and politicians to shut the program down. Huge amounts of energy, time, and money are wasted in this way.

Besides disposal in a landfill, in technologically advanced countries, biosolids can be incinerated (e.g. used as fuel), or used on soils (including in soil products), all of which have benefits and risks. Which approach prevails in any given region seems to be best predicted by two factors:

1. population density – incinerators, with required air pollution controls and other highly technical infrastructure, are not affordable for small communities, and only dense urban areas have a lack of space for wastewater sludge management options such as composting and use on soils; and
2. local social, political – and thus regulatory – preferences for or against incineration.

Thus, wastewater sludge incineration occurs in large cities, but large cities do not always utilize incineration. Many large cities – such as the North American cities of New York, Denver, Los Angeles, and Ottawa – depend on various forms of biosolids recycling to soils. The citizens in Toronto, Ontario, Canada oppose incineration, but there is also public discontent about the concept of use of Toronto biosolids on soils. In this one Canadian province, in 2008, a debate is raging about what constitutes the most sustainable wastewater sludge management practice; this Canadian debate reflects the current debates in other parts of the higher-income world.

As technology advances and population densities increase, a country may turn toward more incineration. This shift is perhaps advancing somewhat more quickly now, because of the current increases in costs of fossil fuel energy. As noted above, Japan (Fujiki), one of the most densely populated countries, relies almost entirely on incineration, as do parts of the northeast USA and northern Europe (e.g. Vienna, and many cities in Germany). The megalopolis of Hong Kong, which has very little agricultural land, is turning away from landfills toward incineration.

Whether or not more large cities will move toward incineration with energy recovery remains to be seen. More policy makers in the developed world still consider it to be a second choice to the recycling of biosolids to soils, the option in which nutrients, organic matter, and energy can all be put to use. But negative public perceptions of biosolids use on soils may dominate, and modern incineration can treat large volumes of wastewater sludge with little visibility and interaction with the public. In contrast, recycling biosolids to soils means bringing a product of wastewater treatment directly into communities, which will always, inevitably, generate some questions and concerns.

That said, in 2008, recycling biosolids to soils appears to be the dominant wastewater sludge management option in use in the highest-income countries – and it is increasing steadily worldwide (Table 10).

In these most developed countries, the two most common treatments prior to biosolids applications to soils seem to be anaerobic digestion and lime stabilization. In many countries, corn is the crop most likely to receive biosolids, but vineyards, orchards, grains, and other crops are also fertilized with biosolids. Many countries discourage or prohibit the use of biosolids on food crops destined for direct human consumption, and, if allowed, there are prescribed waiting periods between application of biosolids and harvesting of crops (see, for example, the USA – USEPA report).

Most of the biosolids used in domestic, horticultural, and green space (landscaping, parks, sports fields) areas are composted; some are heat-dried (e.g. heat-dried pellet fertilizer).

The third largest use of biosolids on soils is as a tool for improving degraded soils at mine sites, construction sites, and other disturbed areas. This practice is well developed in parts of Canada, Europe, New Zealand, and the USA.

The report from Colorado, USA (Stefonick and Hull) and Portugal (Duarte) discuss use of biosolids for stabilizing soils after forest fires. However, uses of biosolids in forests and tree stands are relatively uncommon.

Table 10 underscores the fact that middle and higher-income countries are, in general, moving away from landfilling biosolids to using them on soils and/or – to a lesser extent – incinerating them, with some recovery of energy. Australia, Canada, the Czech Republic, Hungary, Italy, New Zealand, Slovakia, and the USA rely on at least three diverse options for use and disposal of biosolids, including landfill disposal. Germany has similarly diversified outlets, with growing reliance on incineration with energy recovery. Some countries are committed to single options: Norway relies almost entirely on use in agriculture and on green spaces, while Japan relies almost entirely on incineration.

Finally, the development of products (other than soil amendments) from wastewater sludge continues to be explored, but slowly. Incinerator ash and melted slag are being used more and more in construction materials (mostly cement), e.g. at Tokyo, Japan (Nakajima). And several cities around the globe are extracting phosphorus (P) from wastewater sludge and distributing it as fertilizer. But the complex technologies and operational costs required to extract or produce products from wastewater sludge continue to be less cost-efficient in comparison to the traditional, proven options of biosolids recycling to soils, incineration, and landfilling.

Table 10. The most common biosolids use or disposal in middle and higher-income countries

Landfill Disposal (or less managed land disposal)	Incineration, with or without energy recovery & ash use (cities)	Biosolids Recycling to Soils			
		Use in agriculture (crops)	**Domestic and green space use (horticulture, landscaping)**	**Forestland**	**Land reclamation**
Australia		Australia (canola, wheat, oats, etc.)	Australia		
Austria	Austria (Vienna)				
Brazil		Brazil (corn, etc.)			
Bulgaria					
Canada – Ontario		Canada – Ontario			
			Canada – Moncton		Canada – Moncton
		Canada – Ottawa	Canada – Ottawa		
		Canada – Western	Canada – Western		Canada – Western
Canada – Québec	Canada – Québec				
China (China)		China			
Czech Republic		Czech Republic	Czech Republic		
					Columbia
European Union (1996 – 42%)	European Union (1996 – 12%)	European Union (1996 – 36%)			
(2010 – 18%)	(2010 – 23%)	(2010 – 45%)			
			Finland		
	Germany	Germany	Germany		
Hungary		Hungary			Hungary
Iran		Iran			
Italy		Italy	Italy		Italy
	Japan				
Jordan (Jordan)					
(Mexico)					
			Namibia – Walvis Bay		
	Netherlands				
New Zealand		New Zealand			New Zealand
		Norway	Norway		
Portugal		Portugal (corn, vineyards, orchards)			
		Slovakia			
Russian Federation	Russian Federation				
Slovakia			Slovakia		
	Slovenia		Slovenia		
(South Africa)		South Africa	South Africa		
Turkey			Turkey		
USA (30%)	USA (15%)	USA (41%)	USA (12%)		
		USA –Los Angeles, CA (corn, wheat, milo, hay)			
		USA – Denver, CO (wheat)	USA – Denver		
		USA – Delaware (corn, soy, wheat, barley, legume hay)			
USA – Chicago, IL		USA – Chicago, IL			
		USA – Lawrence, KS			
USA –Gr.Rapids, MI					
		USA – Milwaukee, WI	USA – Milwaukee, WI		
	USA – Cleveland, OH				

Each country listed has at least 15% of their sewage sludge treated and used in this way

Temporal comparisons and trends

Increases in excreta capture and wastewater sludge production

In developing countries, the amount of excreta and septage is increasing and should continue to do so as more sewers are built to capture and contain these materials. This means there will be an increasing need for systems to manage, treat, and use or dispose of these materials.

The most common prediction stated in the 1996 *Global Atlas* was this: the production of wastewater sludge would increase in the future. This was a reasonable prediction, because this had been the trend for years. The explanations for steady increases in wastewater sludge production include:

- population growth, which increases domestic and industrial waste discharges,
- stricter regulatory requirements for containing and managing excreta, and
- stricter regulatory limits for wastewater discharges that drive technological improvements that remove more solids and nutrients from wastewater.

Have the 1996 predictions regarding increases in wastewater sludge production been borne out?

Mostly yes (Table 11).

Table 11. Changes in reported sewage sludge production, 1996 atlas to current atlas

Country / Jurisdiction	1996 Atlas Year reported: Sewage sludge managed (dry tonnes / year)	2008 Atlas Year reported: Sewage sludge managed (dry tonnes / year)
Germany	1990: 2,750,000	2003: 2,000,000
Italy	1990: 800,000	2004: 1,000,000
Japan – Yokohama	1994: 3.72 million m3 (2% solids)	2006: 649 million m3 (1.43 % solids)
Netherlands	1990: 280,000	2008: 1,500,000
Norway	1996: 85,000	2008: 86,500
Slovakia	16:55,0	28:56,9

Countrywide data collection is often imperfect. Most of the numbers provided in this *Atlas* are estimates based on calculations of the amount of wastewater solids likely produced per person. This can vary, however, based on the amount of commercial and industry wastewater input and other factors. Thus, the data is useful for general planning purposes, but is not as precise as compilation of actual masses of solids produced and managed. Thus, the reported wastewater sludge production in Germany apparently *decreased* during the past decade, according to *Atlas* reports – which may or may not be true. But in other countries, there has been the expected increase – and, apparently, large increases in some cases, such as at Yokohama, Japan, and in the Netherlands.

Biosolids recycling to soils is increasing

In countries around the globe, from Brazil to New Zealand to North America to Russia, research and demonstration programs are providing increasing local knowledge and experience with recycling of biosolids (treated wastewater sludge) to soils. This research activity is supporting the development of regulations and acceptable biosolids recycling practices in diverse regions and climates. Thus, biosolids recycling to soils is strong (greater than 60%) and growing in Australia, the Czech Republic, New Zealand, and Slovakia (Table 12). Many middle-income countries are developing biosolids recycling programs, and this option is expected to substantially replace landfill or unmanaged disposal in the coming years.

However, in higher-income countries, direct land application of minimally treated biosolids (Class B by U.S. EPA standards) is diminishing. Composting and other treatments to produce biosolids that are used in non-agricultural applications are increasing. This change is part of the steady progress of continual marginal improvements in environmental and public health protections that has been the story of sanitation.

Table 12. The role of biosolids recycling to soils in middle- and higher-income countries

~ 5% and growing (current %)	> 30% and growing (current %)	> 60% and growing (current %)	Holding steady (current %)	Diminishing (current %)	Already very little use on soils
Brazil (15%)	Canada (33%)	Australia (81%)	Italy (69%)	Austria (65%)	Japan (14%)
Bulgaria (~5%)	China (50%)	Czech Republic (67%)	USA (55%)	Germany	Netherlands
Jordan (~0%)	European Union (~40%)	New Zealand (66%)	Norway (~95%)		Switzerland (0%)
Mexico (~0%)	Hungary (39%)	Slovakia (69%)			
Turkey	Portugal				

In comparison, there are relatively few higher-income countries – notably Austria and Germany – that are currently moving away from biosolids recycling to soils. These two countries, Japan, the Netherlands, and some cities in the USA are moving toward more incineration of biosolids with a focus on energy recovery and, especially in Japan, use of incinerator ash in cement and as aggregate fill. Similarly, many cities in many countries are focusing on increasing methane gas production from anaerobic digestion, in large part because of the energy benefits.

Here are some other interesting changes and trends between the 1996 *Atlas* and the current volume:

- In Italy, Spinosa and Ragazzi reported that in the mid-1990s, incineration was going to increase; this apparently did not happen. Today, Spinosa discusses composting at length, and that is expected to increase.
- In the Netherlands, in 1996, 11% of wastewater sludge was used in agriculture and 82% was disposed in landfills, according to Engers. As noted, the Netherlands now sends much of its wastewater sludge to incinerators inside the country or in Germany, some of it after composting or heat drying.
- In contrast, Sapporo, Japan, has not seen any significant changes to its wastewater sludge management program during the past decade.
- In 1996, New Zealand (Harding) reported that Wellington and other municipalities were beginning to explore options for use of wastewater sludge on land – including use in forests – to replace the common practice of landfilling. In 2008, Bradley reports that New

Zealand has adopted a nationwide goal of composting, treating for methane emissions, or otherwise beneficially using 95% of municipal biosolids and commercial organic wastes.

- Bulgaria landfilled all of its wastewater sludge in 1996 – and still does so. However, new national regulations are being developed that should lead to land application and a reduction in landfilling – in accordance with EU directives.

In the developing countries, creating access to basic sanitation for the world's poorest people is the focus, requiring increases in systems to manage the collected wastes. In middle- and high-income countries, the trend is away from landfilling toward incineration or use of biosolids on soils. In high-income countries, land application of minimally treated biosolids to agricultural soils is being slowly replaced by composting and other advanced treatments to produce biosolids for use in non-agricultural settings. Ocean disposal is no longer an option in most developed countries and is being phased out.

Egg digesters in Boston. © NEBRA

Table 13. Comparisons of costs for wastewater treatment, diesel, and electricity around the world and over time

All figures in $ USA	1996 cost of treating m3 of wastewater	2008 cost of treating m3 of wastewater	1996 cost for 1000 liters diesel fuel	2008 cost for 1000 liters diesel fuel	1996 cost of 1 kWh of electricity	2008 cost of 1 kWh of electricity
Australia	$0.51*	$1.14*	$518	$1,234	$0.08	$0.11
Austria	$1.92*	$1.24*	$87	$1,897	$0.14	$0.18
Bulgaria	$0.18	$0.31	$215	$1,298^^	$0.03	$0.59
Cameroon		$120*per truckload to empty latrines		>$1120		$0.12
Canada: Brit. Col.		$0.32		$952		0.05
Canada: Moncton		$0.50		$1193		$0.11
China	$0.04 (at Tianjin)	$0.08	$301	$834	$0.03	$0.09
Czech Republic		$2.93		$1,752		$0.26
England		$0.95 – $5		$2,152		$0.29
Ethiopia		$16.50 per truckload to empty latrines		$742		$0.06
Hungary		$1.39		$1,697		$0.14
Iran		$0.05				$0.03
Italy		$0.39	$864	$1,899	$0.08	$0.26
Japan – Tokyo			$230	$1,272	$0.11	$0.15
Jordan		$2.30		$700		$0.06
Mali		$38.24 per truckload to empty latrines		$1,061		$0.21
Namibia – Walvis Bay		$0.46		$1,143		$0.10
Nigeria		$45 per truck-load to empty septics		$935		
New Zealand	$0.18	$0.73	$340	$990	$0.07	
Norway	$0.77	$2.92	$1,081	$2,292	$0.06	$0.07
Portugal				$1,808		$0.11
Russian Federation		$0.42		$800^^		$0.12
Senegal		$0.35 $28 for sewer connection)		$1,044		$0.17
Slovakia	$0.13	$1.47	$566	$1,764	$0.08	$0.14
So. Africa	$0.14	varies	$399	$1,141	$0.03	$0.04
Turkey		$0.59* (actual total cost ~ $8.00)		$3,588		$0.17
USA	$0.46* (Wisconsin)	$0.25* (Wisconsin) $1.33 (Michigan)	$220 (Wisconsin)	$851 (Los Angeles) $655 (Denver)	$0.14 (Wisconsin)	$0.02 (Los Angeles) $0.06 (Michigan)
Averages			$438	$1,363	$0.08	$0.14

**Average charge to customers (actual costs for treating a m3 are higher, according to authors).*
^^Adjusted or corrected from an Atlas report.

Trends in excreta, wastewater sludge, septage, and biosolids management have not been occurring in a vacuum. Concern about fossil fuel energy and global warming have affected decisions in this field, as much as in any other. The current global focus on energy efficiency and sustainability at wastewater treatment and wastewater sludge management facilities is driven by energy prices. Table 13 explains why there is so much current interest in maximizing energy recovery from biosolids through incineration and anaerobic digestion.

Innovative and notable practices

The reports in this *Atlas* cite a wide variety of innovative and advanced strategies for excreta and wastewater sludge management.

In developing countries, pit latrine design, construction, and management has improved, with ventilation and ease of access for cleaning ("VIP" latrines). Ecosans and composting toilets are being demonstrated and some designs are proving cost-efficient. Community groups and other local organizations are in place to sustainably build and operate collection systems and excreta and wastewater treatment programs. For example, in Nigeria, there are already informal recycling programs run by entrepreneurial scavengers who apply (unfortunately) untreated or (safer) composted septage or fecal waste to agricultural crops. The reports from these countries, below, contain many examples of growing capacity.

This growing knowledge and capacity are capable of producing significant improvements in access to sanitation when financing is available to support it and the building of infrastructure. The advancement in sanitation in eThekwini, South Africa is a good example. At Walvis Bay, Namibia, a wastewater and wastewater sludge management system operates effectively. Other sub-Saharan African countries should be able to reach the same levels of advancement, especially if the higher-income countries make good on their commitments to the Millennium Development Goals and invest the estimated $10 billion over the next seven years needed to halve the number of people without access to adequate sanitation by 2015.

In the more developed countries, there are many demonstrations of cost-effective technologies and systems for treatment and use or disposal of excreta, septage, and wastewater sludge. Many of the best options rely on tried and true approaches, such as anaerobic digestion that stabilizes excreta and wastewater sludges while generating a non-fossil fuel. Here are a few of the many examples, from the reports in this *Atlas,* of leading treatment and management options that are likely to be part of the future of sustainable management of excreta and wastewater sludge:

- Age-old processes are being refined, as in Russia (Gunter & Belyaeva), where drying beds and freeze-thaw dewatering systems are in use; these systems are energy and cost efficient.
- Biosolids have been used around the world for reclamation of damaged lands – and there remain myriad sites where biosolids are the answer to grave environmental damages; for example, Stefonick and Hull discuss the transformation of mine tailings at Leadville, Colorado, USA, into a productive natural ecosystem, and Van Ham notes the extent of biosolids use for gravel mine reclamation in British Columbia, Canada.

- Researchers in North America and Australasia have clearly demonstrated the value of applying biosolids to forests and specialty tree crops, such as hybrid poplars, to increase yields and shorten harvest cycles in intensively managed tree crops.
- Similar research is being done using biosolids to grow fuel crops, such as canola that can be used for biodiesel production; Seattle, Washington, USA is a leader in this, and Turkey (Filibeli) is also conducting research. Refining alcohols and other fuels directly from wastewater sludges, including by pyrolysis and gasification, is a being explored in several places.
- Composting, a tried and true process, has seen many refinements and is one of the simpler, yet most effective, treatments for wastewater sludge. Optimized aerated static pile composting at the Greater Moncton Sewerage Commission in eastern Canada treats odors and trace chemicals in wastewater sludge, producing an appealing compost product. GMSC innovation has resulted in recovery of heat from the process to provide interior heating and ice melting in winter.
- In Japan, researchers have demonstrated the effectiveness of anaerobic co-digestion of wastewater sludge and rice straw, producing increased volumes of methane and improving the quality of the wastewater sludge.
- The Czech Republic is a leader in using lysis and thermophilic anaerobic digestion to stabilize wastewater sludge and improve energy recovery. Prague doubled biogas production from 7 million m^3/year in 1993 to more than 16 million in 2005 due to use of a lysing centrifuge and new thermophilic digestion.
- Slovenia produces 2.5 million kWh annually from wastewater biogas, and some of the country's anaerobic digesters co-digest wastewater sludge with separated municipal organic waste, such as food waste; similar co-digestion occurs in Norway and cities in North America and Europe.
- Solar drying and, perhaps, carbonization of wastewater sludge are processes that can produce dry solids using less energy than conventional dewatering techniques; this means that the resulting wastewater sludge can be burned and yield a net gain of energy.
- Processes are being developed, like the Seaborne process, which recovers nitrogen, some heavy metals, and, especially, phosphorus from wastewater sludge in a complex process involving digestion and methane production; such advancements may eventually further optimize putting biosolids to their best possible use.
- Local programs that land-apply treated and tested (Class B by U.S. EPA standards) biosolids to local farmlands continue to prove cost-effective and environmentally sound, as long as dewatering and transportation fuel use and costs are kept as low as possible. Simple, low-technology systems like this should not be overlooked as sustainable solutions. Such systems, when carefully managed with farmer and public involvement, are often the best options for developing countries working their way into beneficial uses of treated excreta and biosolids.

Innovative technologies and systems are not all that is needed to advance the best uses of treated excreta and biosolids. Laws and regulations are at least as important. Several outstanding and innovative regulatory concepts from the reports in this *Atlas* are worth highlighting:

- Industrial pretreatment and pollution prevention programs that reduce or eliminate discharges of potentially toxic substances (heavy metals, chemicals) to excreta and wastewater management systems are crucial for protecting the sustainability of biosolids recycling to soils. Many countries report focusing on this, including New Zealand, the Russian Federation, and the USA. Slovakia (Sumna) notes: "the most serious problems with excessive sludge contamination related to industrial waste water discharging into public sewer system is considered as a solved issue in the Slovak Republic."
- Most more-developed countries have – or are creating – regulatory systems that address the three major concerns about wastewater sludge management: pathogens and stabilization (vector attraction reduction), heavy metals, and chemical contaminants. Québec, Canada, has a notable three-part classification system: the C classification refers to the concentration of heavy metals, the P classification refers to the level of pathogens, and the O classification refers to the amount of malodor generated by the biosolids. This O classification builds on and goes further than any other country's stabilization requirements, helping to ensure that nuisance odors – the most common cause of complaints about biosolids recycling to soils – are avoided.
- Semi-voluntary and voluntary quality management programs have been developed in England (Matthews) and the USA (see Klamm's report about Kansas). The Safe Sludge Matrix in England was developed with the input of diverse stakeholders and has addressed concerns raised by farmers, food companies, and the public about the safety of biosolids use on food chain crops. In the USA, the U. S. Environmental Protection Agency and two national water quality professional organizations formed the National Biosolids Partnership (NBP) in the late 1990s and have been advancing Environmental Management Systems (EMS) to ensure biosolids programs are well-run, always in compliance, and constantly advance beneficial environmental outcomes. Kent County, Delaware, USA (Newton) has achieved certification for an NBP EMS, as well as an ISO 14001 EMS.
- Because biosolids recycled on soils or as fuels provide significant environmental benefits, regulatory structures should help stimulate and encourage their use. In Québec, Canada, a tax imposed on landfilling wastewater sludge helps make recycling to soils more cost-competitive. In the USA, the EPA has included composts and fertilizers made from "recovered organic materials," including biosolids, in it list of products that must be used, if at all possible, when federal funding is provided for a project; this helps to stimulate demand for biosolids products.

A GLOBAL BIOSOLIDS AGENDA: CHALLENGES AND THE WAY FORWARD

Wastewater sludge production increases

As shown above in Table 7, as sanitation improves in developing countries, and as the level of treatment improves in developed countries (i.e. as more cities add secondary and tertiary treatment, and as coastal cities abandon ocean disposal), the production of wastewater sludge increases. Campos describes the situation in Colombia this way: "As residual water treatment has low coverage, sludge management in Colombia is an area that has hardly started to grow, but will become an issue of great significance in the near future as the coverage improves." Garcia et al. put it this way: "In Mexico, an increase in wastewater treatment will pose a challenge in terms of safe treatment and sludge management. This, together with significant soil degradation observed in the country (close to 64% of the total soil surface is degraded according to INE, 2007) creates an opportunity to reuse biosolids."

In contrast, the most developed countries in the world are now seeing a leveling of wastewater sludge production numbers, because most of their population is now connected into the wastewater management infrastructure, either directly or indirectly (i.e. via septic systems). Thus, Schulte notes that, in Germany, "a substantial increase of sewage accumulation in future is not expected due to the existing high connection degree to the public distribution network and thus to sewage treatment plants."

If developing countries were to attain a level of sanitation coverage and wastewater sludge production per person equivalent to that of developed countries, the volumes of wastewater sludge that each country would have to manage would be on the order of those in Table 14. Thus, 2.5% of Jordan's agricultural area and 1% of China's would be required each year to receive the nation's biosolids. In most countries, only a fraction of a percent of agricultural area would be needed.

Managing this increasing volume of contained excreta and wastewater sludge will pose significant challenges to these countries. As planning progresses and investments are made in sanitation improvements, they must include planning and investments in treating and managing wastewater sludge. Building excreta and wastewater collection and treatment systems is one step, but as challenging is the inevitable need to manage wastewater sludge. In the most developed countries, such as Norway, the cost of this aspect of sanitation reaches as high as 50% of total sanitation expenditures.

Table 14. Estimates of future wastewater sludge production if developing countries attain levels of wastewater service coverage of developed countries

Country	Estimated future sludge production (Mg)	Estimated future sludge production Mg/ha of agricultural area	% of agricultural area req'd to apply country's future sludge at 5 dry Mg/ha
Brazil	4,069,339	0.015	0.309%
Bulgaria	159,793	0.030	0.607%
Burkina Faso	300,811	0.028	0.552%
Cameroon	375,191	0.041	0.819%
China	28,429,686	0.051	1.022%
Colombia	943,197	0.022	0.443%
Côte d'Ivoire	381,988	0.019	0.376%
Ethiopia	1,617,928	0.048	0.954%
Hungary	215,96	0.037	0.737%
Iran	1,486,172	0.031	0.624%
Jordan	127,801	0.126	2.526%
Mali	253,51	0.006	0.128%
Mexico	2,324,823	0.022	0.433%
Mozambique	425,945	0.009	0.175%
Namibia	44,228	0.001	0.023%
Nigeria	2,852,972	0.039	0.771%
Russia	3,091,705	0.014	0.287%
Senegal	259,358	0.031	0.629%
South Africa	956,062	0.010	0.192%
Turkey	1,523,506	0.037	0.739%

Agricultural area data from UNEP, obtained from http://geodata.grid.unep.ch/results.php "Agricultural area" is the sum of arable land and permanent crops, plus permanent pastures.

Average sewage sludge per capita production calculated from data presented for 11 countries: Canada, Czech Republic, Finland, Germany, Italy, Japan, Norway, Portugal, Slovenia, United Kingdom, and USA.

Pressures on biosolids recycling to soils

If the same per capita sludge production rate discussed above (Table 14) is applied to the populations and agricultural areas of developed countries, it becomes evident why Germany, the Netherlands, and Japan have shifted away from biosolids recycling to soils, especially considering the competition from animal manures for supplying nutrients (Table 15). The USA is included, for comparison.

Table 15. Estimated percentage of agricultural area required to apply countries' wastewater sludge

Country	Estimated sludge production (Mg)	Estimated sludge production Mg/ha of agricultural area	% of agricultural area req'd to apply country's future sludge at 5 dry Mg/ha
Germany	1,783,323	0.105	2.1%
Netherlands	356,816	0.186	3.7%
Japan	2,757,856	0.588	11.8%
United States	6,457,264	0.0156	0.3%

Population density and the availability of agricultural lands for biosolids recycling to soils will continue to put pressure on recycling biosolids to soils and influence decisions on how best to manage excreta and wastewater sludge.

Alongside those constraints are additional social and political factors. For example, even though Norway hypothetically would need to utilize 1.9% of its agricultural area to land apply all of its biosolids – a percentage approaching that of Germany – it remains committed to biosolids recycling to soils and expects to continue to do so in the coming years. There is clearly a relatively high level of acceptance by Norwegian farmers and public. Norway's success with biosolids recycling is described by Blytt: ".In order to achieve the high rate of land applied sludge, stringent standards have been set for the content of heavy metals and pathogens, and the control of the odour nuisance has been given high priority. In fact the Norwegian regulation concerning sludge is stricter than those of most of the countries in Europe." The level of public understanding and support is a major determinant in whether or not a country recycles significant portions of its wastewater sludge to soils. Therefore, public consultations are becoming more common and involved in many developed countries.

Middle-income and low-income countries should expect the same and make plans – early in the process of developing wastewater management policy – regarding how they will manage and treat excreta and wastewater sludge. They can build their programs more effectively and efficiently by considering lessons learned in developed countries:

- Obtain stakeholder (farmers, other land owners) and public input early in the planning process for excreta management and wastewater treatment.
- Include planning for wastewater sludge management from the start.
- To avoid future public and environmental pressure to shift toward more costly incineration, design sanitation systems that keep significant levels of toxic elements (heavy metals) and chemicals (POPs, PPCPs, etc.) out of excreta, wastewater, septage, and wastewater sludge. Institute and enforce industrial and commercial pretreatment programs from the start, as collection systems are developed.
- Develop stringent regulatory controls that encourage the recycling to soils of high-quality biosolids and other organic residuals in integrated, nutrient management systems.
- Consider local public preferences for how biosolids are used; if there is perceived concern about use of biosolids in food chain crops, develop regulatory structures and systems that encourage uses for reclamation, on green spaces, and forest products.
- Maximize energy efficiencies in the design and operations of wastewater sludge management programs, including utilizing appropriate, simpler technologies – such as solar drying (dewatering) – to reduce fossil fuel use and associated costs. Maximize energy recovery from wastewater sludge where possible, such as by anaerobic digestion.
- Conduct local research and demonstration projects, with the involvement of diverse stakeholders, to show the benefits of biosolids recycling to soils, and fine-tune best-management practices for the local situation.
- Keep political leaders, regulators, and the public informed and involved.

Financing will always be an issue for development of sanitation and advanced excreta and wastewater management systems. But the benefits of investments in these systems are quite obvious and can be demonstrated easily to most people. Waste and wastewater managers must, however, remain vocal and visible to ensure that politicians and other policy makers understand the importance of what they do. In developing countries especially, national and local leaders, as well as development aid programs, need to be urged to make sanitation a higher priority – and with the understanding that the management of treated excreta and wastewater sludge must be included in sanitation plans and funding.

Technical issues will continue to require research, and best management practices for biosolids management will continue to evolve. For example, the potential for excessive phosphorus to be applied to soils through biosolids and animal manures may require application of developing technologies for removal of phosphorus. Likewise, current issues about trace chemical contaminants in biosolids used on soils will continue to require support for research and analysis of risks.

The challenge is, however, for policy makers and leaders in the biosolids management field to keep in mind the "big picture" and assess the relative value of addressing relatively small risks of, for example, trace pharmaceuticals in land applied biosolids in developed countries versus the value of creating sustainable adequate sanitation for the 2.6 billion people who don't yet have it.

A broad policy for global biosolids management

What is going to prove most sustainable in the long term?

As the reports in this *Atlas* show, there is a recognizable progression from the development of basic sanitation through rudimentary wastewater treatment with landfilling of wastewater sludge to increased regulated recycling of treated wastewater sludge (biosolids) to soils. Some cities and densely populated countries diverge from biosolids recycling to soils and opt for the more complex technology of incineration – and this is becoming more common as concerns are expressed about contaminants in biosolids applied to soils and fossil fuel prices rise and incineration is perceived as a potential source of renewable energy.

Whether this new trend toward incineration will continue is uncertain. A recent evaluation of wastewater sludge use and disposal options for the city of Chengdu, China, (Murray et al., 2008) found incineration of wastewater sludge to be much more costly in terms of total life-cycle costs economically and environmentally – including impacts on greenhouse gas emissions. In contrast, the most sustainable option was treatment by anaerobic digestion followed by some form of use on soils that offsets fertilizer use, such as composting.

Practical considerations

If proper excreta management and biosolids recycling to soils are to continue to advance, they must continue to be made ever more "safe, sustainable, and welcome," in the words of Peter Matthews of the Sustainable Organic Resources Partnership in the United Kingdom (and one of the editors of this *Atlas*).

Safety and sustainability will continue to be advanced by ongoing research and further development of regulations and best management practices. For example, soil quality criteria are important for controlling the application of biosolids and any other soil amendment and fertilizer, in order to protect sustainable uses of soils. Safety and sustainability are also assured by management and enforcement systems that assure that all biosolids are properly treated for pathogens, are managed according to regulations, and do not have any deleterious environmental impacts. Voluntary quality management programs, such as the USA National Biosolids Partnership Biosolids Environmental Management System (EMS), are designed to help do this and ensure continual improvement.

But an excreta, wastewater sludge, and biosolids management program can be safe and sustainable, but still not be "welcome." There are several different groups of stakeholders who must welcome a particular management program for it to be viable over the longer term:

- Farmers and other users of biosolids products must want the products and consider them safe and beneficial.
- The neighbors and communities where biosolids are applied to soils must see the value and benefits and be willing to put up with occasional nuisances, such as truck traffic or occasional malodor.
- The users and operators of sewers and other excreta and wastewater management systems must be willing to pay the required fees or taxes. In other words, the programs must be cost-efficient.

What does sustainability mean?

- *Dealing transparently and systemically with risk, uncertainty, and irreversibility.*
- *Ensuring appropriate valuation, appreciation, and restoration of nature.*
- *Integration of environmental, social, human, and economic goals in policies and activities.*
- *Equal opportunity and community participation.*
- *Conservation of biodiversity and ecological integrity.*
- *Ensuring inter-generational equity.*
- *Recognizing the global integration of localities.*
- *A commitment to best practice.*
- *No net loss of human capital or natural capital.*
- *The principle of continuous improvement.*
- *The need for good governance.*

adapted from Wikipedia

The likely future is emerging

Based on current understanding and experience with excreta and wastewater sludge management worldwide, as described in the reports in this *Atlas,* the current dominant trends seem to be pointing toward a sustainable future that involves the following:

- Adequate sanitation must reach all people, which means more excreta, wastewater sludge, and biosolids will need management.
- Nutrients, organic matter, and energy are resources in excreta and wastewater sludges that should be utilized as best as possible.
- Anaerobic digestion and other biological treatments, like composting, provide proven and safe treatments of excreta and wastewater sludges while reducing chemical contaminants and, especially in the case of anaerobic digestion, producing energy.
- Applying properly treated excreta and biosolids to soils in accordance with robust regulatory and best management programs provides numerous benefits to soils and crops, while offsetting uses of fossil fuel-based resources such as fertilizers.
- Proper management of excreta and wastewater sludges can significantly reduce releases to the atmosphere of powerful greenhouse gases such as methane and result in carbon sequestration in soils. This is an increasingly important aspect of the management of these materials, and properly managed programs that recycle biosolids to soils are likely to prove the best options in comparison to incineration and landfill disposal.
- Where population densities make it impossible to recycle to soils, the best uses for treated excreta and biosolids will be energy recovery through anaerobic digestion and/or incineration or other thermal treatment with recycling of the resulting ash.

> *"A more harmonized legislative and policy framework across the country for management of biosolids is seen as an important objective by the wastewater industry and advocates of sustainable environmental practices."*
>
> *– Ellison and Jefferson, in the report from Canada, below*

Moving forward the sustainable and welcome uses of a global resource

The development of sanitation around the world over the past century has created the knowledge and technology necessary to bring adequate sanitation to all people and safely manage the collected excreta. The challenge in 2008, the International Year of Sanitation, is to further disseminate this knowledge and technology in developing countries, helping them leap-frog forward to sustainable, cost-efficient systems. What is needed?

1. *Funding* – More funding is needed for basic sanitation infrastructure and capacity building in developing countries, and steady, carefully prioritized funding is needed for established systems in developed countries to maintain and improve on current gains. The value of sanitation cannot be over-emphasized.

2. *Public Education and Consultation* – Increasing public understanding and support of the value of sanitation is critical. In all countries, sanitation is the most important basic function for protecting public health, wellness, and the environment. The only other equally important basic functions are maintaining potable drinking water, producing food, and providing shelter – and sanitation is integral to the first two of these. The knowledgeable public should be involved in decision-making regarding excreta and wastewater sludge management, so that policies and programs are supported and investments are not made in systems that will be shut down due to public concerns.
3. *Policy* – Developed countries have reached a shared understanding of what is required to advance proper, sustainable sanitation and wastewater sludge management and create legal and regulatory structures to support these functions. We are ready for international policies that promote biosolids use on land as part of the integrated recycling of organic residuals to soils – a necessary part of sustainable food production systems and healthy soils. This knowledge should be used to help developing countries create policies and regulations that advance the recycling of treated excreta and biosolids. Policies and regulatory structures should reflect the will of the public, as well as local technical and environmental constraints. For example, if a particular local community cannot overcome the innate dislike for use of anything associated with human waste in food production, there are plenty of uses for biosolids on non-food chain soils and crops.
4. *Research* – Continued research and demonstrations, especially at the local level, will be needed to assure communities of the benefits and limited risks of biosolids recycling to soils. Research into new systems and technologies should be carefully prioritized to focus on developing practical advances that are energy- and cost-efficient.
5. *Technology* – For most of the world, simpler technologies – especially those that rely on natural biological systems, such as anaerobic digestion and composting – must be the priority technologies for energy- and cost-efficient excreta, wastewater sludge, and biosolids management.

CONCLUSION

The development of waterborne waste systems appears to be inevitable, especially in densely populated areas. As economies grow, improved treatment of wastewater is necessary and infrastructure is built. Initially, these sanitation systems are focused on reducing the risks of disease. But as development progresses, protection of the environment in general becomes an increasingly important goal. In 2008, the International Year of Sanitation, much of the developed world has an effective wastewater treatment infrastructure. The course these countries have followed over the past century and more provides a model for developing countries to follow as we aim to reduce the number of people lacking access to basic sanitation from the current level of 2.6 billion.

a global biosolids proclamation

Whereas excretion is a biological requirement, and

Whereas human excreta contain pathogenic organisms, and

Whereas the health and safety of human communities requires sanitation, and

Whereas 2.6 billion people live without access to adequate sanitation, and

Whereas the development of sanitation begets the need to manage excreta and wastewater, and

Whereas managing excreta and wastewater inevitably result in wastewater sludge that must be managed, and

Whereas this wastewater sludge contains plant nutrients and organic matter that is beneficial to soils and crops, and

Whereas worldwide scientific research and decades of experience have developed methods for treating, regulating, and properly managing wastewater sludge in order to ensure minimal risks to public health and the environment when the resulting biosolids are used as soil amendments and fertilizers, and

Whereas the only other viable accepted options for use or disposal of biosolids are incineration and landfill disposal, and

Whereas advancing scientific understanding of global warming and greenhouse gas emissions indicate that organic materials in landfills are a significant source of methane and incineration requires substantial energy and infrastructure and has other environmental impacts, and

Whereas biosolids recycling to soils is being shown to have net positive impacts on greenhouse gas emissions, including reduced use of fossil fuel-derived fertilizers, and

Whereas biosolids recycling to soils involves attention to industrial pretreatment, pollution prevention, and keeping clean the waste stream, which helps ensure that substances that are bad for the environment are not used or disposed, and

Whereas biosolids have many proven benefits to soils and crops, including increasing organic matter, adding micro-nutrients, reducing erosion, increasing water holding capacity, and improving tilth, and

Whereas biosolids recycling to soils can be a cost-efficient, local solution for the final disposition of wastewater sludge,

Therefore, we urge all Earth's communities and nations to advance programs that put to their best use the resources – nutrients, organic matter, and energy – in excreta and wastewater sludge, to the extent reasonably possible, as determined by local professionals and the communities with which they work.

For these goals to be reached, this proclamation will need the strong support of water quality and waste management professionals worldwide, their professional organizations, environmental and agricultural groups, research scientists and academic institutions, international development agencies, other NGOs, political leaders at all levels of government, regulatory agencies, the media, and the general public.

As this effort for basic sanitation for billions continues, spurred in part by the Millennium Development Goals, the most developed countries are wrestling with the next major issue associated with sanitation: how to maximize the sustainability of wastewater sludge management programs in a world facing climate change. In this latest environmental challenge, proper management of excreta, wastewater sludge, and biosolids is a solution waiting to be fully realized.

REVIEW OF LITERATURE AND RESOURCES

Managing excreta, wastewater sludge, and biosolids is the focus of decades of research at universities and in governmental agencies in countries around the world, with thousands of published scientific papers available on topics such as the benefits to soils and crops, heavy metals in soils and crops and animals eating the crops, the fate of particular chemicals in wastewater treatment and biosolids application to soils, and the effectiveness of pathogen reduction processes. International scientific conferences on wastewater sludge and biosolids management have occurred regularly for many years. The World Health Organization has created guidance, and biosolids management is covered by the International Organization for Standards (ISO), the European Committee for Standards (CEN), the U. S. Department of Agriculture, the U. S. Food and Drug Administration, and other standards-setting and regulatory organizations around the world. The International Water Association (IWA), the Water Environment Federation (WEF), and other engineering and water quality professional organizations support ongoing research, education, and training. The latest IWA conference on biosolids management was held in Moncton, New Brunswick, Canada, in June 2007 – and representatives from more than 40 countries attended and shared information on advances and challenges in their fields of specialization.

"Andreoli and Pegorini (2006) state that the use of wastewater sludge cannot be confused as a simple way for sanitation managers rid themselves of this problem, but in contrast, the recycling concept demands the adoption of technological alternatives that maximize the benefits through the use of beneficial components of the residues, carefully considering the environment and sanitary risks, to generate safe and economical viable alternatives that will guarantee the sustainability of the process."

– Andreoli et al., in the report from Brazil, below

In addition to the scientific work that has been done, numerous governmental agencies review the science as they develop policies and programs for the management of excreta, wastewater, wastewater sludge, and biosolids. The U. S. Environmental Protection Agency conducted a major risk assessment in advance of promulgating its 1993 national biosolids management regulations at 40 CFR Part 503 – and the documentation of that work provides useful guidance. The European Union's 1986 Sludge Directive and subsequent policies are also based upon the extensive scientific literature.

Recommended biosolids resources

- International Biosolids Network: *http://www.internationalbiosolidsnetwork.org/*
- International Water Association: *http://www.iwahq.org*
- European Union: *http://ec.europa.eu/environment/waste/sludge/index.htm*
- Environmental Protection Agency (USA): *http://www.epa.gov/owm/mtb/biosolids/*
- National Biosolids Partnership (USA): *http://www.biosolids.org*
- Canadian Biosolids Partnership: *http://www.cwwa.ca/cbp%2Dpcb/*
- UN Habitat Water and Sanitation Programme: *http://www.unchs.org/categories .asp?catid=270*

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Australia

Author: Allen Gale

Australia

STRUCTURE OF THE AUSTRALIAN WATER INDUSTRY

Australia consists of six states and two territories. Australia is a federation established in 1901 by the then six British colonies in Australia uniting under a single constitution. As may be expected, each colony (state) had established its own way of doing business, which resulted in major differences, even in simple things such as rail gauges. Each state had, and still retains, responsibility for water management (although this is being seriously challenged at present).

Each state has a different structure for water management. For example, in Western Australia, which constitutes one-third of Australia, there is one water corporation responsible for bulk and retail water services for some 2 million people. On the other hand, New South Wales (NSW) (total population 6.8 million) has one water corporation for Sydney (some 4.2 million people) and more than a hundred local government councils administering water supply for the remaining 2.6 million people in NSW, with many servicing only a few thousand people. Victoria has a single bulk supplier and three retailers servicing its 3.2 million people in Melbourne, The remaining 1.8 million people of Victoria are serviced by 13 retailers.

Each State and Territory has its own biosolids guidelines or standards. There are many similarities across all guidelines, but there are differences that cause confusion and uncertainty to the general community. These include limits for heavy metals that have a major impact on the classification of biosolids for land application.

Geographic, climatic and soil conditions vary widely across Australia, which also impacts on the most appropriate biosolids management systems.

Consequently there is no "typical" biosolids management system that applies readily across Australia.

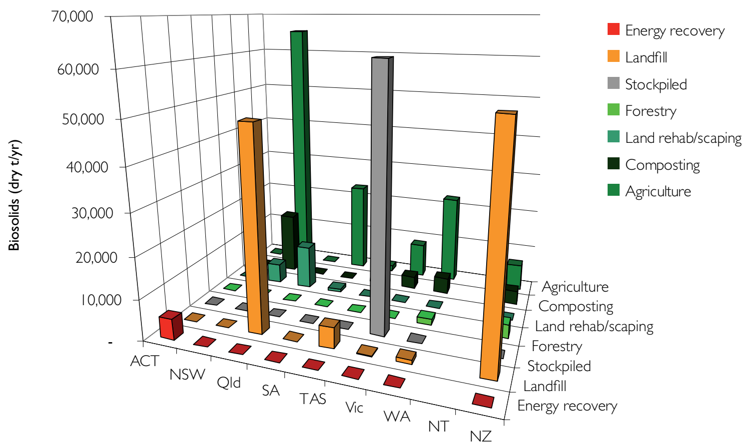
BIOSOLIDS IN AUSTRALIA

Currently approximately 360,000 dry tonnes of biosolids are produced annually in Australasia (Australia and New Zealand), (see *Figure 1* for state by state quantities and usage). The cost for sludge/biosolids management is typically 35 to 50 percent of total capital and operating cost for wastewater treatment. It will cost water authorities and users of water hundreds of millions of dollars in the coming years to manage biosolids (the current average cost for biosolids management is in the order of $300/dry tonne, which equates to about $100M per year).

The most common use of biosolids is land application, although substantial quantities are stockpiled, some for many decades. Victoria alone has a stockpile of some 1.7M dry tonnes of biosolids. Landfill is not considered a beneficial use of biosolids and is not, or soon will not, be an acceptable option in any state or territory. Landfill is still accepted in New Zealand. The Australian Capital Territory's Lower Molonglo plant is the only one in Australia to use energy recovery (incineration), a practice which has been in place for several decades. Incineration was practiced in other states in the 1970's and 1980's but the practice ended for a number of reasons, including high costs and emission issues.

All major facilities dewater and/or dry biosolids. No major facilities land apply liquid biosolids.

Figure 1. Annual production and uses of biosolids in Australia (State/Territory) and New Zealand



Regional examples

Three regional examples have been presented, to demonstrate the range of approaches to biosolids management. These are:

- Perth, Western Australia
- Adelaide, South Australia
- Shepparton, Victoria

PERTH METROPOLITAN WASTEWATER TREATMENT PLANTS: OPERATED BY WATER CORPORATION

Background

Western Australia has a land mass of 2.5 million square kilometres and a population of 2.4 million (2006) with approximately 1.5 million residing in Perth. The Water Corporation owned by the Western Australian Government, owns and operates 101 wastewater treatment plants (WWTP's). The Perth Metropolitan area has three major WWTP's and 6 minor WWTP's (< 15 ML/d). The smaller WWTP's tanker their solids to the major WWTP's for processing.

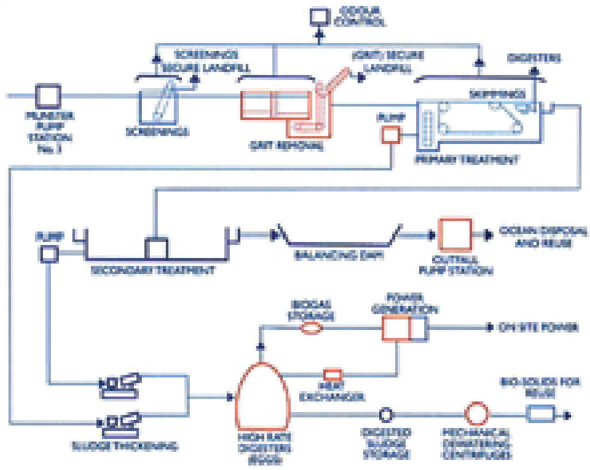
Woodman Point wastewater treatment plant

Woodman Point WWTP is an advanced secondary treatment plant with mesophilic anaerobic digestion, located 30 kilometres south of Perth CBD. The original Woodman Point plant was opened in 1966 but was relocated in 1984 to its current position on an 82 hectare site. In 2002, a AU$150 million upgrade to the plant increased its capacity from 125 million litres to 160 million litres per day.

The Woodman Point WWTP discharges 110 million litres per day of treated effluent approximately 4 kilometres offshore from an underwater outlet into the 20 metre deep Sepia Depression west of Point Peron.

Anaerobic digested sludge is transferred to a blending tank prior to dewatering by centrifuge. From the centrifuge the biosolids cake is transferred to 4 x 75 tonne overhead hoppers which are emptied daily. Total biosolids onsite storage is approximately 8 days (6 days liquid + 2 days cake).

Figure 2. Schematic of the Woodman Point WWTP



Beenyup wastewater treatment plant

Beenyup WWTP is an advanced secondary treatment process with 2 stage mesophilic anaerobic digestion, located 25 km north of Perth CBD. The first stage of the current Beenyup WWTP was commissioned in 1972 and catered for a flow of 3.6 million litres per day. This treatment plant has encountered numerous upgrades over the years including a gravity outfall system which enabled the treated effluent to be discharged into the Marmion Marine Park (Indian Ocean) into 10 metres of water via two outlets, one 1850 metres and the other 1650 metres offshore. In 2005 state of the art odour control was added and the plant's capacity increased to 120 million litres per day. The future design for this WWTP is to treat 150 million litres per day, servicing a population of up to 750,000 people. Liquid biosolids are drawn from the secondary digester for dewatering done by centrifuges. The dewatered cake is transferred to one 150 tonne overhead hopper and removed daily by trucks for beneficial use. Onsite storage capacity is approximately 3 days (2 days liquid + 1 days cake).

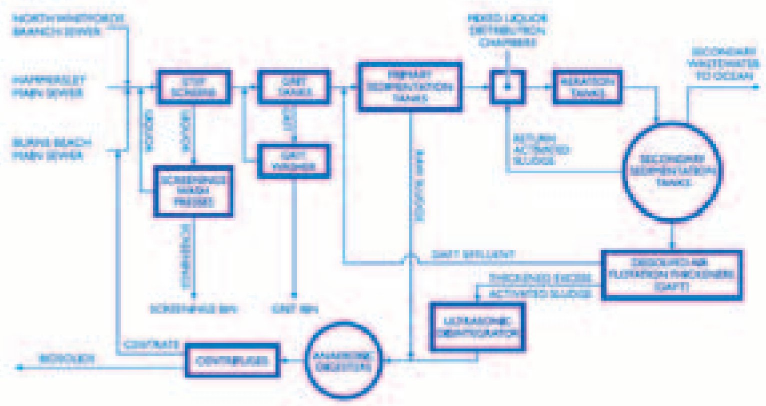
Subiaco wastewater treatment plant

The Subiaco WWTP is located 7 kilometres west of the Perth CDB and treats domestic wastewater mainly collected from the Perth central metropolitan area, but the sewerage catchment does extend to Perth's eastern suburbs. This WWTP was commissioned as a treatment works in 1927 as part of the Subiaco Sewerage Scheme. In 1961 and 1981 the plant was redeveloped and expanded to provide a advanced secondary treatment. The most recent upgrade to the plant was completed in 2004, and was aimed primarily to provide a very high level of odour control. The Subiaco WWTP is designed to treat up to 61.4 megalitres per day equivalent to a population of 350,000 people.

Approximately 55 million litres of treated effluent is discharged 1 kilometre offshore from a 10 metres deep underwater outlet off Swanbourne beach.

The combined raw sludge and thickened excess activated sludge is pumped to centrifuges, where it is partly dewatered, producing a sludge cake. Lime is then mixed with the cake (lime amended biosolids) to increase the pH of the material to destroy pathogens.

Figure 3. Schematic of the Beenyup WWTP



Economic information

The costs of operations are as follows:

- Typical proportion of sewerage operation costs attributable to sludge are 35%-45% Capital, Operations and Maintenance
- Cost of 1000 litres of diesel fuel : $1511
- Cost of one kilowatt hour of electricity: 7.9-10.5c/kWh

Benchmark sludge / biosolids

The Water Corporation produce two types of biosolids products; biosolids cake which is stabilised by anaerobic digestion, and dewatered and lime-amended biosolids, which is raw sludge (and excess activated sludge) dewatered by centrifuge then stabilised with the addition of lime.

The Perth Metropolitan WWTP's produced 20,100 dry tonnes of biosolids from July 2006 to June 2007.

The Water Corporation have three established markets available for beneficial use of biosolids, direct land application for broad acre crop production, composting and direct application to forestry stands (pine plantation). In exceptional circumstances, typically due to issues of seasonal access to agricultural land, biosolids may be land filled.

Other options considered

In 2000 the Water Corporation commissioned the Enersludge™ process, which was designed to produce a diesel-grade oil from sludge (OFS). This was a three-part process and included a sludge dewatering and drying process prior to Enersludge™ process. The OFS component of the process was decommissioned in Nov 2001 and the drying process was decommissioned in Dec 2003. The remaining process, lime amended biosolids process remains in operation.

Although land application of biosolids is considered scientifically sound, the Water Corporation considers community perception (either real or perceived) of land applied biosolids as a potential risk and therefore is not considered a long term option. As a result the Water Corporation is investigating alternative beneficial uses for biosolids, which include co-combustion, fuel substitution, sludge reduction process.

Biosolids compliance

Regulation of biosolids is done by the Department of Environment and Conservation (DEC) who are the authors of the state biosolids guidelines, The Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products, Feb 2002 (WA Biosolids Guidelines), which are not mandatory and are currently under review. However, land users wishing to receive more than 1000 wet tonnes of biosolids over a 12-month period must apply for a Licence under the *Environmental Protection Act 1986*. Licences are issued with legally binding conditions that apply to specific premises and are intended to prevent or minimise potential for pollution. Furthermore, prosecution by the DEC can occur with or without a licence if pollution of the environment occurs. An extract from DEC's WA Biosolids Guidelines is presented in Appendix 1.

Strategic selection of utilisation practices

Biosolids at the Woodman Point WWTP and Beenyup WWTP are stabilised via mesophilic anaerobic digestion prior to centrifuge dewatering to an average of 20% dried solids producing a Grade C2 P3 product (see appendix 1).

Monitoring of solids retention time, digester temperatures and pH are conducted daily with volatile solids reduction (%) across the treatment process calculated weekly.

The Subiaco WWTP produces a lime amended biosolids (LAB) whereby raw sludge is stabilised by the addition of lime. Once the lime is added pH is measured and again after 8 hours prior to the biosolids being transported to farmland. Typical solids are 30–35% DS producing a Grade C2 P1 product although as the LAB is not further dried to >50% DS (as per the WA Biosolids Guidelines) an agreement was made with the regulators to downgrade the pathogen criteria to P3 with the condition the LAB be land applied within 7 days of production.

For direct land application of biosolids, application rates are calculated using a total biosolids loading. When consideration is given for the soil phosphorus retention index, biosolids application rates are limited by plant nitrogen requirements. To date biosolids application rates have never been limited by contaminants.

The Water Corporation uses the WA Biosolids Guidelines for assessing direct land application of biosolids. These guidelines consider environmental, public and livestock health risks. Further, site evaluations are conducted before, during and after biosolids have been applied. The Water Corporation uses strategic planning to determine market sustainability rather than through community engagement.

Community engagement

For biosolids applied directly to land, consultation is limited to notifying and holding discussions with immediate neighbours of the proposed application sites.

On a larger scale the Water Corporation has a communication strategy to promote awareness and provide education of biosolids that includes:

- Attendance at agricultural field events
- Monthly media advertorials (district newspaper where biosolids are applied)
- Updating the Water Corporation biosolids webpage
- Updating the biosolids poster display and fact sheets
- Community presentation
- Regulatory presentations
- Employee presentations (within Water Corporation)

Transportation

The Water Corporation developed and published a Transport Management Plan for biosolids. Biosolids dewatered cake is transported in 40-tonne loads. The trucks and trailers have sealed and locked tailgates and hydraulically operated solid lids. This system reduces odour and spills during transport. The LAB is hauled in fully enclosed silos with payloads of 30 tonnes. All biosolids haulage is on contract for the supply of service for three- to five-year terms.

Direct land application

The direct land application program commenced with broad acre agriculture trials in 1997. Since this time there has been a great demand for biosolids, resulting in more customers than can be supplied. By mid 2007 the Water Corporation advertised nationally and forwarded an Expressions of Interest (EOI) for biosolids to all customers who had made biosolids requests over the past 10 years. The Water Corporation considered this a fair and transparent way to select future biosolids customers. One of the key aspects of the EOI is to secure biosolids outlets for five-year terms.

Biosolids storage facility

To assist with the management of biosolids, including fly controls (Health Act 1986 states it is illegal to breed flies in Western Australia), the Water Corporation has proposed to construct a Biosolids Storage Facility (BSF). If constructed, this facility will assist with issues of seasonal availability of land for the application of biosolids to broad acre agriculture, which typically only have one crop rotation per year and the limited storage capacity at the WWTPs. A trial will of the facility (to be operated for 18 months) is expected to be commissioned late 2008. It is anticipated the trial will be followed by a full scale BSF, designed to store approximately 36,000 wet tonne of dewatered cake for up to eight months per year.

Broad acre agriculture

It is common for Agricultural soils throughout much of Australia, and particularly Western Australia to suffer from nutrient deficiencies and/or soil acidity. Direct land application of biosolids has shown marked improvements in soils and crop production when applied in these areas, which is reflected by the high demand for biosolids in the agricultural regions. Biosolids are applied to land utilising tractor-drawn manure spreaders. Application rates are calculated by determining the contaminant loading, nutrient loading and plant nutrient requirement with the lesser value determining the final application rate. Perth metropolitan biosolids are applied at either plant nutrient requirement (N) for broad acre crops such as canola, wheat, oats (for dewatered cake) or soil pH requirement (for lime amended biosolids).

The application rate for nitrogen assumes that 15% of the total nitrogen is mineralised whilst phosphorus is assumed to have 21% available P to the plant. Biosolids dewatered cake is currently applied at rates of 8 dry t/ha while LAB is applied at 13 dry t/ha. Biosolids applications are usually followed by incorporation into the soil within 36 hours. Cost to the Water Corporation[1] to directly apply biosolids to broad acre agriculture ranges from AU$115 – AU$190 per dry tonne and is dependant on product type and transport distance.

1 *Costs include: soil sampling and analysis, biosolids analysis, approvals and licences, transportation, provision and maintenance of manure spreader, plant mobilisation and entomology monitoring.*

Forestry

Application of dewatered biosolids cake in forestry plantations began following a three-year research project in 1998. Typically biosolids are applied at 30 dry tonne per hectare to 12- to 18-year-old trees. Application is done using a modified side discharge spreader attached to a "forwarder" (designed for operating in plantations). These biosolids are not incorporated into the soil. Following the biosolids application, site restrictions are placed on the area and signage is used to notify the public of the biosolids application. The Water Corporation is in the process of engaging the Forestry Products Commission on five-year contracts for the application of biosolids. It is estimated that 12,000 tonne at 20% DS will be applied to forestry per annum. Cost to the Water Corporation[2] to directly apply biosolids in forestry is estimated to be AU$150 per dry tonne.

Composting

The Water Corporation currently has two contractors who take biosolids for further processing with soils, green waste and some municipal waste and produce an unrestricted composted biosolids product, the majority of which is used by householder and landscapers. Until recently, composting contractors were engaged for three-year terms, however as of 2008, five-year terms will be used. An estimated 21,000 tonnes at 20% DS is utilised by this market per annum. Cost to the Water Corporation ranges between AU$120 to AU$325 per dry tonne.

Landfill

Disposal of biosolids to landfill is not commonly used in Perth and has only be used in emergency circumstances such as loss of access to agricultural or forestry locations. The biosolids contingency plan has identified 10 alternative options with diversion to landfill being the last resort.

If disposal of biosolids to landfill is required, the gate fee is $65 per wet tonne plus transportation at $12 per wet tonne

Incineration

There is no incineration of biosolids in Western Australia.

For more information contact the Water Corporation of Western Australia:
www.watercorporation.com.au

2 *Costs include: biosolids analysis, approvals and licences, transportation, provision and maintenance of manure spreader, plant mobilisation and a fee subsidy for application contractor*

Appendix 1 – West Australian biosolids guidelines

Contaminant	C1 (mg/kg)	C2 (mg/kg)	C3
Arsenic	20	60	Untested or greater than grade C2
Cadmium	3	20	
Chromium (total)	100	500	
Copper	100	2500	
Lead	150	420	
Mercury	1	15	
Nickel	60	270	
Selenium	3	50	
Zinc	200	2500	
DDT/DDD/DDE	0.5 (total)	1 (total)	
Aldrin	0.02	0.5	
Dieldrin	0.02	0.5	
Chlordane	0.02	0.5	
Heptachlor	0.02	0.5	
HCB	0.02	0.5	
Lindane	0.02	0.5	
BHC	0.02	0.5	
PCB's	0.3	0.5	

Pathogen Grade	Maximum Pathogen Levels	Treatment Methods that Typically Achieve the Requisite Pathogen Levels
P1	Grade P1 Salmonella – less than 1 count per 50g of dry product. AND Thermo-tolerant Coliforms – less than 100 counts per gram of dry product.	Digested and then composted in a vessel, heated at >55°C for a 3 day period. OR Composted in a windrow, turned 5 times and maintained at >55 °C for a 15 day period. OR Maintained at a pH >12 for a 3 day period, heated at >53 °C for a 12 hour period, and dried to >50% solids. OR Heated to >80 °C and dried to >90% solids and the product kept dry until used. OR Digested and dried to solids >10% and then stored for >3 years.
P2	Salmonella – less than 10 counts per 50g of dry product. AND Thermo-tolerant Coliforms – less than 1000 counts per gram of dry product.	Composted at >53 °C for a 5 day period. OR Composted at >55 °C for a 3 day period. OR Heated to 70 °C for 1 hour and then dried to >90% solids. OR Digested, heated to 70 °C for 1 hour and then dried to >75% solids. OR Aerobic thermophilic digestion (55-60 °C for a 10 day period), with a volatile solids reduction of >38% and total solids reduction of >50%.
P3	Thermo-tolerant Coliforms – less than 2,000,000 counts per gram of dry product	Anaerobic digestion at 35 °C for 20 days with a volatile solids reduction of >38%. OR Anaerobic digestion at 15 °C for 60 days with a volatile solids reduction of >38%. OR Aerobic digestion at 20 °C for 40 days with a volatile solids reduction of >38%. OR Aerobic digestion at 15 °C for 60 days with a volatile solids reduction of >38%. OR Aerobic composting at >40 °C for 5 days, including a period of at least 4 hours at >55 °C.
P4	Thermo-tolerant Coliforms greater than 2,000,000 counts per gram of dry product	Untreated or inadequately treated.

ADELAIDE METROPOLITAN WASTEWATER TREATMENT PLANTS OPERATED BY SA WATER

Background

Adelaide has four wastewater treatment plants at Bolivar, Bolivar High Salinity, Glenelg and Christies Beach.

Wastewater is received at each plant and the processes used include preliminary treatment, primary treatment for solids removal, activated sludge treatment and anaerobic sludge digestion. The Bolivar plant also incorporates polishing lagoons that further treat the effluent produced by the activated sludge plant before discharging into the environment. The effluent is disinfected for marine discharge or further treated to enable reuse in parks, market gardens and as a secondary supply to communities. The sludge produced from the Christies Beach and Bolivar plants has always been dewatered in evaporation lagoons. Sludge from the Glenelg plant was disposed to sea via marine outfalls. In 1993, a 34 km pipeline was commissioned to convey the digested sludge to lagoons at the Bolivar plant for solar drying. At Bolivar there are now a total of 110 ha of lagoons dedicated to solar drying of sludge.

Biosolids processing

Digested sludge enters the lagoons at about 1 to 2% solids. Supernatant is decanted from the lagoons when full to accelerate the drying process. A water cap is retained on the lagoons to prevent the release of odours of any residual sludge digestion in the lagoons. The dried sludge is removed for stockpiling at Bolivar at about 40 to 50% solids. Stockpiling in large heaps for up to four years results in a final solids content of about 80%. Table 1 summarises the annual biosolids production.

Table 1. Biosolids production – Metropolitan Adelaide (2006/07)

Wastewater Treatment Plant	Sewage Inflow ML/d	Annual Output (DryTonnes/year)
Bolivar	148	17,685
Glenelg	46	3,092
Bolivar High Salinity	23	Incorporated in Bolivar total
Christies Beach	26	1,890
Total	243	22,667

With the increased volatile solids loading, the sludge evaporation lagoons became a potential source of odours. Alternative sludge dewatering and stabilisation processes have subsequently been implemented to take about a third of the digested sludge production from the Bolivar plant, with the remainder dried in the evaporation lagoons but with a lower volatile solids loading. The alternative process comprises mechanical dewatering of digested sludge by centrifuge, achieving about 20% solids content. After centrifuging further dewatering is carried out using the air agitated drying process (AAD). This involves forming windrows of centrifuged sludge mixed with dried sludge which are then regularly turned using a Backhus windrow turning machine to assist drying.

Dried, digested biosolids contains about 1 to 1.5% each of phosphorus and nitrogen and 0.5% potassium. Representative concentrations of other elements of interest are shown in table 2 below.

Table 2. Typical analysis of digested biosolids used for agriculture

Parameter	Typical value	Parameter	Typical value
Organic carbon	5.2%	Arsenic	6 mg/kg
pH	7.2	Cadmium	3 mg/kg
Sulphur	0.7%	Copper	800 mg/kg
Calcium	3.5%	Lead	150 mg/kg
Manganese	0.8%	Mercury	1.5 mg/kg
EC 1:5	6.0 dS/m	Nickel	60 mg/kg
		Zinc	900 mg/kg

The effluent treatment process at Bolivar also incorporates six stabilisation lagoons with a total area of 347 ha. Four of these lagoons were desludged in the mid 1990's producing about 130,000 dry tonnes of sludge which has been added to the stockpile at Bolivar. This stabilisation lagoon sludge has lower nutrient concentrations than the digested material, and also lower metal concentrations.

SA biosolids guidelines

The South Australian (SA) guidelines (1996) use a combination of grading standards for stabilisation and threshold metal concentrations to define various reuse classifications. The current edition is being revised and the draft revised guidelines are discussed further.

There are two stabilisation grades and three grades for contaminant grading. The contaminant grading classification and stabilisation grading requirements are presented in Appendix 2.

The draft SA biosolids guidelines differ from other guidelines in two main ways:

- There is no classification that permits unrestricted use of biosolids. This minimises the risk of contamination of crops due to an increase in the metals concentrations as the organic component of the mix degrades.
- The maximum annual application rate of biosolids for agricultural uses must not exceed the metal contaminant loading rates to reduce the risk of large quantities of metal application to soils. In South Australia, cadmium is the limiting contaminant with a value of 0.15 kg/ha per 5 years.

A maximum biosolids application rate is determined from consideration of the assimilative capacity of the topsoil, the limiting annual loading rate for metals in the biosolids (Contaminant Limiting Application Rate – CLAR) and the nutrient load (Nutrient Limiting Application Rate – NLAR). The low nitrogen and phosphorus concentrations in the biosolids means that maximum annual loading rates are determined usually by the concentration of copper or cadmium in the biosolids and not by the nitrogen application as is typically the situation with "fresh" mechanically dewatered biosolids.

The SA Biosolids Guidelines do not allow use on land that is or is likely to be used in the future for vegetable production. The reasons for this restriction are:

- In South Australia all vegetable crops are irrigated and the chloride in the irrigation water is known to increase the bioavailability of metals, cadmium in particular.
- Many vegetables, in particular root crops, accumulate metals in the edible parts of the plant more readily than other crops such as cereals or permanent plantings with a woody structure.

For land application, the Guidelines have certain site characteristics restricting the use of biosolids. These preclude application to soils with a pH less than 5.5, the requirement of certain buffer zones and non-application to sites that can cause runoff, such as stony or sloping ground. Care is also exercised to ensure no adverse impact on ground or surface waters.

A revision of the SA Guidelines is expected. The new publication will formalise the draft procedures and include other changes that have been acted upon over several years.

Biosolids use

Land application

Biosolids use started in South Australia in the late 1960's when the Bolivar wastewater treatment plant was commissioned. A fertiliser company paid to remove and take the sludge from the drying lagoons each year. The only requirement for use without restriction was heat treatment in a kiln to reduce pathogen concentrations. The product was used as a base for a number of organic fertiliser mixes and sold throughout Australia. A 100% biosolid product known as Humus Booster was used on a range of horticultural crops. This activity eventually ceased in the early '90's due to increased handling costs, competition from animal manures and concerns about the metal content of biosolids originating from industrial discharges. SA Water then started to accumulate a stockpile of dried digested sludge.

The South Australian Biosolids Guidelines were published in 1996 and SA Water investigated methods of reuse. Following the unsuccessful call for expressions of interest and based on the Sydney experience of land application, SA Water decided to make biosolids available for reuse in accordance with the EPA Guidelines and to develop markets. This was considered as the lowest cost and most practical option.

The Guidelines initially prohibited application on irrigated crops such as vegetables, vines and citrus (previous main uses). Land application could only continue to dryland arable farms producing grains such as cereals, pulses or oilseeds. The current usage program commenced in 1998 when approximately 2,000 tonnes were provided to 15 farmers who showed interest following a presentation to a land care group just prior to the seasonal break. This has now grown into a programme where approximately 30,000 product tonnes per annum are applied to agriculture by about 130 different users. The quantity taken by each user varies from 100 to more than 1,500 tonnes. The annual quantity taken varies according to climatic and economic conditions.

Biosolids are made available free of charge, provided that at least 100 tonnes are taken in the first year of use. SA Water arranges at its own expense all the procedures and approvals required by the EPA. The approval under the Guidelines requires a property inspection, collection and analysis of topsoil samples and preparation of a sketch map showing the location of the reuse site in relation to roads, property boundaries, water courses etc. The EPA approval is valid for ten years. The user pays for the transport of biosolids to the reuse site and the cost of spreading onto the paddock. Whilst the maximum rate permitted for application of the biosolids under the guidelines is generally between 15 and 25 tonnes/ha, most cereal farmers apply the biosolids at 5 tonnes/ha and horticultural users apply it at about 10 tonnes/ha.

Application rates are generally a compromise between the cost of transport, spreading, phosphorus content and the organic content of the biosolids. Most farmers apply biosolids to new paddocks each year rather than repeat applications to the same paddock. Reports from farmers indicate that the benefit of applying the biosolids lasts for three years after the first application. Farmers on light soils receive the greatest benefit from using the biosolids.

The biosolids are harvested from the lagoons each summer and stockpiled to complete the stabilisation process but contain large lumps. They are screened or milled at SA Water's expense prior to release for easy and even application by farmers who use their own spreading equipment. Most biosolids are collected during autumn and taken directly to the paddocks where it is to be used and incorporated into the soil within one month of spreading.

The costs of biosolids management are confidential and thus cannot be made available.

Other uses

SA Water has also released small quantities of biosolids for landscaping purposes.

It is also considering using biosolids centrifuge cake as a feedstock to existing large scale commercial compost operations of green wastes collected by Municipal organisations.

The SA Guidelines (1996) did not initially allow use of biosolids on any irrigated crop, however, continued interest from grape, olive and citrus growers led to a review. It was concluded that there was little risk of metal uptake and transference of metals to the edible part of plants for permanent plantings such as vines, citrus, stonefruit and olives, and such use was allowed.

During 2000/2001 some concerns were raised about the use of biosolids on vines. These were followed up and it was concluded that they were based on public perception rather than health, quality or sustainability. Consequently the use of biosolids on vineyards has diminished. This was disappointing as previous users have seen the benefits and there does not appear to be any documented adverse impact of the biosolids on wine quality.

Landfill of biosolids is not permitted in South Australia.

For more information contact SA Water corporation:
www.sawater.com.au

Appendix 2 – South Australian biosolids guidelines

Table 1. Contaminant classification of biosolids according to metal concentration

Contaminant	Grade A (mg/kg)	Grade B (mg/kg)	Grade C (mg/kg)
Arsenic	20	20	60
Cadmium	1	11	20
Copper	100	750	2500
Lead	200	300	420
Mercury	1	9	15
Nickel	60	145	270
Zinc	200	1400	2500

Table 2. Acceptable stabilisation processes and stabilisation grading classification

Stabilisation Grade	Process to Achieve grade
A	Long term storage (Digestion + ageing >3 years + drying >75% solids) Composting processes Lime stabilisation Pasteurisation Other processes demonstrated to be equivalent
B	Medium term storage (Digestion + ageing >1 year + drying>75% solids) Aerobic/ anaerobic digestion Partial Composting Partial Lime stabilisation Agitated Air Drying process (60 days processing and final product of 50% solids or greater) Other processes demonstrated to be equivalent

Stabilisation grade A: <100 E.Coli per gm total solids
<1 Salmonella per 50 gm total solids.
<1 virus per 50 gm total solids
<1 viable Helminth ova per 50 gm total solids

Stabilisation grade B: <1,000 E.Coli per gm total solids

The Guidelines specify permitted uses of the biosolids depending upon their classification as listed in the following Table. In addition to these classification requirements and permitted uses, there are threshold concentrations for metals in soils used for commercially produced food chain crops. These are identical to Contaminant Grade A values.

Table 3. SA biosolids guidelines – classification requirements

Minimum Grade		**Uses not requiring**	**Uses Requiring**
Stabilisation	Contaminant	EPA Notification	EPA Notification
A	A	Home Garden Urban Landscaping Forestry Site Rehabilitation	Agriculture (non-irrigated) Irrigated Permanent Plantings
A	B	Urban Landscaping Forestry Site Rehabilitation	Agriculture (non-irrigated) Irrigated Permanent Plantings
B	B		Agriculture (non-irrigated) Irrigated Permanent Plantings, Forestry Site Rehabilitation
B	C		Agriculture (non-irrigated) Irrigated Permanent Plantings, Forestry Site Rehabilitation
Fails B	Fails C	Landfill	

Note: The use of Biosolids for intermediate landfill cover requires EPA notification.

SHEPPARTON WASTEWATER MANAGEMENT FACILITY VICTORIA

Operated by Goulburn Valley Water Corporation

Background

Goulburn Valley Water (GVW) is one of 13 regional urban water authorities in regional Victoria. GVW provides urban water and wastewater services to a population of over 120,000 in 54 towns and cities from the outskirts of Melbourne in the south to the Murray River in the north.

GVW operates 26 Wastewater Management Facilities across the region. The facilities vary, but predominantly utilise lagoon based treatment processes.

The Shepparton Wastewater Management Facility (WMF) is one of the largest inland WMF's in Victoria servicing an equivalent population of 1.1 million on an organics basis. The annual inflow to the WMF is approximately 6500 ML of which 25% is from major industries. The major industries in the Shepparton area are fruit processing plants and the waste loads from industries are seasonal with the Biochemical Oxygen Demand (BOD) loading on the plant varying from a normal 24T/day up to 80T/day during the peak season.

Process overview

The Shepparton facility consists of mechanical screening to remove large material, grit removal, and chemical dosing for alkalinity control before the wastewater enters the covered high rate anaerobic lagoon to further reduce BOD and suspended solids. This is followed by a series of mechanically aerated lagoons, facultative lagoons and aerobic lagoons prior to the maturation lagoons and recycled water storages. In total there are 19 lagoons covering 155 hectares. Approximately 60% of the recycled water is reused on land for irrigation with the remaining 40% being tertiary treated to reduce phosphorus levels prior to being discharged to the Goulburn River during the winter months.

From sludge surveys carried out on the Shepparton lagoon system, the annual accumulation rate of biosolids is approximately 2000T/year. Based on filling the aerated lagoons with biosolids to 40% of total capacity at an average of 6% solids, the anticipated desludging frequency will be once every 15 years.

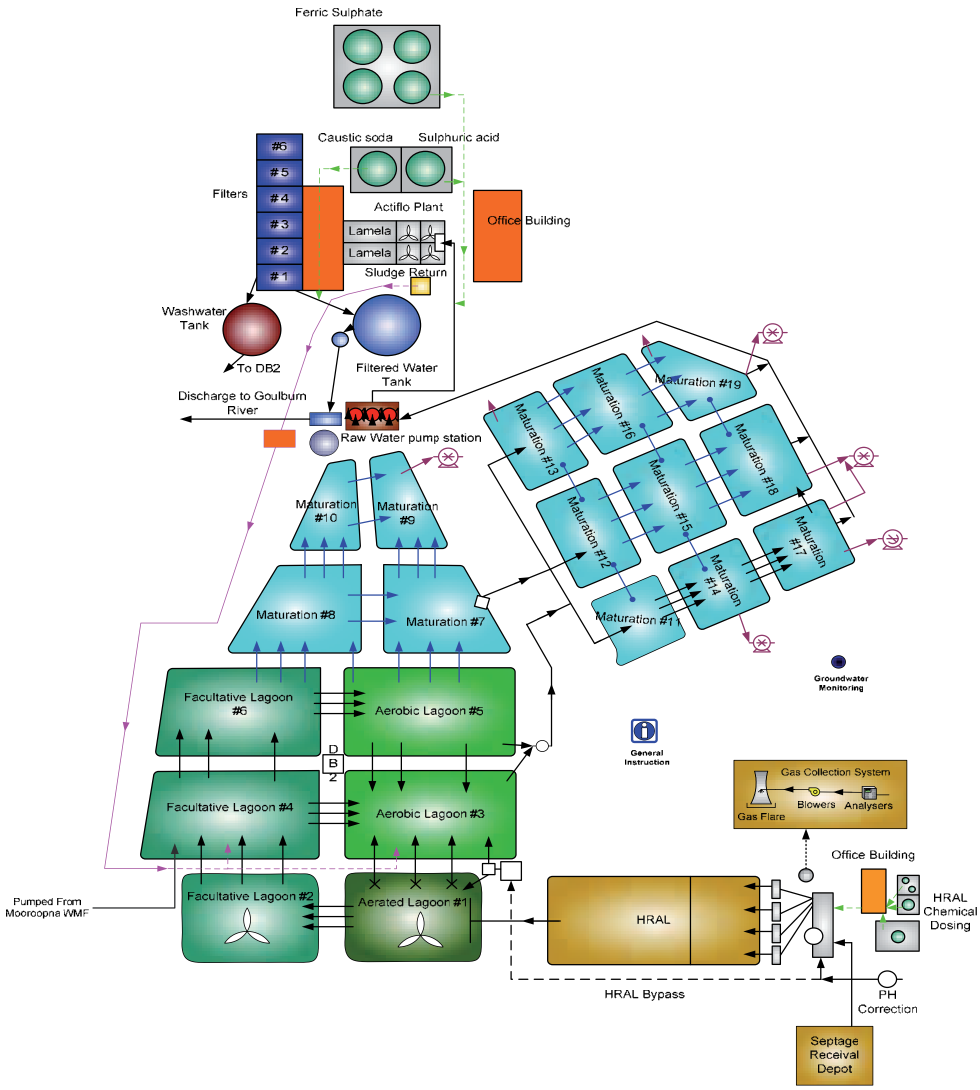
Biosolids were removed from the Shepparton lagoons in 2003/04 and remain in a stockpile containing approximately 44,000 dry tonnes. The biosolids will be beneficially used over the next 2 years as final cover material for landfill sites to help establish vegetation/pasture.

History

In 2003 GVW developed and submitted to the Environmental Protection Authority (EPA) a Sewage Sludge Management Strategy which outlined sustainable sludge management practices for all its WMF's. This strategy was recently updated (March 2007) to meet the changing needs of the industry.

In April 2004, the EPA released the Guidelines for Environmental Management – Biosolids Land Application (Publication 943).

Figure 1. Schematic of the Shepparton WMF



Compliance guidelines

Treatment grading

Three treatment grades are described in the EPA Guidelines: T1, T2 and T3. These grades are primarily based on satisfying three main criteria;

- the adoption of a prescribed treatment process with minimum performance criteria.
- microbiological limits to demonstrate that the defined processes are operating effectively; and
- measures for controlling bacterial regrowth.

T1 represents the highest quality grade and from a microbiological perspective is suitable for unrestricted use.

The classification of the treatment grading of the biosolids is a critical success factor for the biosolids management program. There are restrictions on end use of the biosolids depending on this classification. GVW has undertaken a rigorous testing program of its Shepparton biosolids to determine the actual treatment classification.

The majority of the Shepparton samples of air dried biosolids analysed for E.coli and Salmonella indicate the biosolids meet the T1 requirements. In the few instances where the T1 quality standards are exceeded after drying, sampling has shown that stockpiling the biosolids short term (in the order of 12 months) allows the T1 standard to be achieved.

The restrictive treatment criteria established by the EPA Biosolids Guidelines currently prevent GVW from classifying its anaerobically digested and air dried biosolids as T1/T2 even though it has been shown by testing to meet the relevant quality criteria. GVW is negotiating with the EPA to change its guidelines and to recognise the high quality of the biosolids achieved by the treatment processes in place at the Shepparton plant.

Goulburn Valley Water's Sewage Sludge Management Plan is based on the biosolids being classified as T2 or T1. Incorrect classification of the biosolids as T3 would adversely impact public perception and the acceptance of the end product, which could then impede opportunities for beneficial reuse. Consequently, resolution of the biosolids treatment standard is of high importance.

For further details on treatment grading see Appendix 3.

Contaminant grade

The classification of the biosolids relies on both the treatment grade and the contamination grade. Two contaminant grades are described in the EPA Guidelines: C1 and C2. These grades are primarily based on satisfying contaminant concentrations. Contaminants outside the C1 and C2 limits are not covered in the EPA guidelines.

C1 represents the highest quality grade from a contaminant perspective. Biosolids use can be generalised as unrestricted grade material achieving both the C1 and T1 classifications.

The heavy metal constituents of the biosolids sampled at Shepparton are typically compliant with C1 requirements, with the exception of one metal, zinc. The concentrations of zinc in the biosolids only marginally exceed the C1 thresholds and are comfortably within the C2 classification for contaminants.

Dry Solids	**81%w/w**
Organic Matter	N/A
Zinc	232mg/kg
Copper	80mg/kg
Nickel	18mg/kg
Mercury	0.3mg/kg
Cadmium	0.7mg/kg
Lead	35mg/kg
Total Nitrogen	7440mg/kg
Total Phosphorus	4800mg/kg

Appendix 3 presents the various classes of biosolids and their limits for land application, taken from the EPA's *Victoria Biosolids Land Application Guidelines (Publication 943)*.

Biosolids management practices

The most common desludging and dewatering methods employed in biosolids management for lagoon based treatment systems is dredging and air drying in drying bays or air drying in-situ within a lagoon.

Dredging – wet sludge is removed from a lagoon at a solids concentration of around 4-6% utilising either floating dredges or pumps on pontoons. The sludge is pumped to a handling area for dewatering and drying.

The drying process is normally undertaken on specially constructed temporary drying beds or pans, although diversion to another empty lagoon for in-situ air drying is also common. The provision of supernatant draw off and excess liquid return systems are necessary.

Figure 2. Mechanically assisted drying in bays at Shepparton WMF

Photo © Allen Gale

Drying of the sludge relies on evaporation and the process typically involves turning the semi-dried sludge with mechanical plant to achieve a moisture content of 70% dry solids or better.

The costs involved are usually limited to pumps to remove the excess liquid from the lagoon, mechanically assisting drying with either swamp bulldozers and attachments or excavators, and loaders and trucks when removing the dried solids from the lagoon. The approximate cost for this work is $200 per dry tonne.

Strategic selection of biosolids utilisation

Biosolids at around 70% dry content have the consistency of dry topsoil and are very friable. This allows application at the final use site using conventional fertiliser spreading equipment. This type of equipment is readily available within the Goulburn Valley Water region.

Site rehabilitation, in particular on landfill sites, is a preferred option for biosolids beneficial use. Site rehabilitation typically requires large quantities of biosolids on an intermittent basis. Numerous mine sites and refuse tips have been identified across the region where site rehabilitation using biosolids is possible. Additionally, major roadwork projects present the opportunity to use significant quantities of biosolids in landscaping applications. Blending biosolids with top soil for landscaping applications can also be a viable option based on T1/C2 biosolids properties.

The cost of transporting and spreading of biosolids for landfill capping varies depending on the distance of transportation. The costs are either met by the municipal council or shared with GVW. Transportation and spreading costs range from $20 to $40 per dry tonne.

Biosolids can also be applied to cropping land near wastewater management facilities. At this time it will be a single application per site until such time as data from current research work confirms that multiple applications are feasible and sustainable. Goulburn Valley Water will continue involvement with, and support, research into biosolids management issues in conjunction with other key industry stakeholders.

GVW is continuing to explore other biosolids applications to compliment its preferred options of site rehabilitation and broad acre cropping.

Use made of risk assessment in selection

The selection of biosolids management systems was based on a risk assessment approach undertaken as part of the Sewage Sludge Management Strategy.

Community engagement

Community engagement has been limited to regulators the local municipal councils and neighbours adjacent to the landfills.

The limited community engagement has come about because the needs of the local municipal councils for landfill capping material overtook the original biosolids management strategy of broadacre land application.

A more extensive communications strategy involving the wider community is currently being developed. This will include education and awareness campaigns along with benefits and potential uses for biosolids.

Economic information

- Proportion of Annual Cost (operation and finance charges) of wastewater treatment and disposal attributable to sludge treatment. – the annual costs are low because the sludge is stabilised in facultative and aerated lagoons, with desludging only being required once every 15 to 20 years. On the basis of 2,000 dry tonnes per year and $240/dry tonne to dry to 70% solids, transport and spread, the proportion of annual costs attributable to sludge treatment is approximately 15%.

- Charge to customers for treating one cubic metre of sewage – the charge is complicated by the significant contribution of major food processing industries to the total loads to Shepparton WMF. Major customers are charged for organics, nutrients and salt. Taking these parameters into account, along with volumetric charges, major customers pay approximately $0.60 to $0.90 per cubic metre, depending on waste characteristics.
- Domestic customers pay a fixed service charge of about $255 per property per year. On this basis the domestic charge is $1.30 per cubic metre.
- Cost of Diesel Fuel – diesel fuel costs $1,400 per 1,000/litres.
- Cost of Electricity – electricity charges vary depending on whether it is off-peak or peak time. The average is 12¢ per kWH. Green energy, which is a growing component in Australia, costs approximately 18¢ per kWH.

Other options for biosolids management

Landfill

Disposal of biosolids to landfill is not classified as beneficial use and is not permitted by the Victorian EPA.

Incineration

Incineration is not considered a viable option for lagoon based, highly stabilised biosolids.

Land application to arable land

The biosolids produced from the Shepparton WMF are suitable for use as a soil conditioner that improves soil structure and fertility levels, although they have not been used for land application beyond research trials. Based on experiences at other sites, prior to land based reuse, GVW would undertake community consultation and education programs in nearby areas to minimise any negative response from neighbouring property owners.

The biosolids application rate would be based on existing soil quality data and the biosolids would be applied in accordance with the EPA guidelines. This requires specified cultivation methods and stock withholding periods to be undertaken. All community engagement and application activities/calculations are discussed in detail in the Environment Improvement Plan (EIP) that is prepared for each site.

Product for use in domestic or horticultural markets

There are no immediate opportunities in the GVW area for the development of this type of market. However, consideration is being given to mixing biosolids with composted green waste to provide an economical top soil product.

Use in forests/woodland, conservation and non-sporting recreation land, land reclamation?

This would be similar to the application to arable land but with a reduced level of community consultation.

Production of by products

There are no immediate opportunities in the GVW area for the use of biosolids in by products such as vitrified glass products, construction materials, fuel pellets, oil etc.

Disposing of faecal waste from facilities not connected to mains sewerage

Faecal wastes consist of septage from septic tanks. These are collected by private operators who discharge to an independently operated septage receival station adjacent to Shepparton WMF. The septage passes through grinders and is pumped into the head end of Shepparton WMF, for treatment in conjunction with the wastewater. This does not present any issues as the quantities of septage are relatively small, even allowing for the high organic content.

For more information contact Goulburn Valley Water:
www.gvwater.com.au

Appendix 3 – EPA Victoria biosolids land application (Publication 943)

Classification of biosolids and limits for land application.

- Ensure awareness of the relevant legislation, codes and guidelines relevant to the use of biosolids.

User (restricted grade)

- Enter into an agreement with the supplier (3.1);
- Identify and assess the risks posed by the use of biosolids (3.2);
- Develop and adhere to an EIP (EPA or EPA appointed auditor endorsed) in partnership with the supplier (3.1); and
- Ensure an EPA works approval and licence, or site-specific exemption is obtained if the end use scheme does not meet the guideline requirements.

4. BIOSOLIDS CLASSIFICATION

Classification of biosolids is based on two independent factors, namely the contaminant concentrations in the biosolids and the microbiological quality post treatment. The classifications within these factors are:

(i) Contaminant Grade (C1 or C2) based on biosolids contaminant concentrations (4.1); and

(ii) Treatment Grade (T1, T2, T3) based on the treatment technology utilised, microbiological criteria and measures used to inhibit bacterial regrowth, vector attraction (such as insects or vermin) and odour (4.2).

Biosolids can be generalised as 'unrestricted' or 'restricted' quality, with unrestricted grade material achieving both the C1 and T1 classifications.

Restricted grade material (e.g. C2/T1, C1/T2,...) requires land application management controls (Chapters 5 and 6) to ensure protection of the environment, public health and agriculture (e.g. food safety).

Material that falls outside these grades for either contaminants (considered as C3) or treatment (considered as T4) is not covered under this guideline. Land application of such material may require an EPA works approval and potentially licensing.

This guideline describes the minimum requirements for sustainable biosolids management.

4.1 Contaminant grades

4.1.1 Biosolids contaminant grades

The highest quality biosolids contaminant grade is termed C1. C1 biosolids have sufficiently low contaminant levels that specific management controls on end use are not needed. The C1 limit has been derived for individual contaminants based on a conservative scenario – protecting the most sensitive land use from the application of biosolids as a complete topsoil replacement. Therefore, the C1 limit is adopted from the most stringent soil investigation values for protection of:

- human health in residential scenarios (e.g. protecting children that ingest soil) as per the Health Investigation Level (HIL) in the (NEPM) (*Assessment of Site Contamination*) 1999;
- the environment as defined by the Ecological Investigation Level (EIL) in the above NEPM; and

Table 1. Coefficient based on sample number for calculating BCC

Sample size (n)	Coefficient (a)
5	0.95
6	0.82
7	0.73
8	0.67
10	0.58
11-14	0.52
15-20	0.44

Improving contaminant grading

Processes such as composting, lime stabilisation or soil blending may result in a final product that meets the C1 provisions despite the initial biosolids material being C2. In this instance, provided the final product is re-sampled and conforms to the C1 criteria, the final product can be classified as C1.

Treatment processes that produce a C2 product from C3 material will not typically be accepted if the process involves dilution. Case by case assessment and endorsement will be required in these circumstances.

Table 2. Contaminant upper limits for classifying biosolids as grade C1 or C2 (values are mg/kg dry weight).

Contaminant	Grade C1 and RSCL[1]	Grade C2
Arsenic	20	60
Cadmium	1	10
Chromium[2]	400	3000
Copper	100 (150)[3]	2000
Lead	300	500
Mercury	1	5
Nickel	60	270
Selenium	3	50
Zinc	200 (300)[4]	2500
DDT & derivatives	0.5	1
Organochlorine pesticides[5]	0.05	0.5
PCBs	0.2	1

Table notes

1. Refer 4.1.3 for varying the RSCL.
2. Chromium (III) limit due to expectation that this will be the dominant form.
3. 150 mg/kg copper limit for biosolids products composted to AS 4454.
4. 300 mg/kg zinc limit for biosolids products composted to AS 4454.
5. Organochlorine pesticide limit applies individually to: dieldrin, aldrin, chlordane, heptachlor (and the epoxide), hexachlorobenzene and lindane.

hydrocarbons, compounds that are released from both domestic and industrial/commercial sources. Recently published reviews have indicated that these compounds are not typically present in sufficient concentrations in biosolids to necessitate inclusion in the current guideline.

Dioxin-like compounds

An investigation level of 50ng TEQ/kg, considering polychlorinated dibenzo-*p*-dioxins (PCDDs) polychlorinated dibenzofurans (PCDFs) and coplanar polychlorinated biphenyls (PCBs), is included for biosolids. The levels should be calculated based on World Health Organisation recommendations (den Berg et al., 1998). Where dioxin levels exceed 50 ng TEQ/kg, restrictions on sensitive end uses such as cattle grazing or dairy uses should be implemented. The need for management controls on other end uses should also be considered. For comparison, the US EPA is proposing a biosolids dioxin limit of 300 ng TEQ/kg, while the EC is proposing 100 ng TEQ/kg.

Testing for dioxin-like compounds is not automatically required. Sewage treatment plants receiving significant quantities of chlorinated trade wastes or other potential sources of dioxins should consider the need for a dioxin screen based on a composite sample(s).

Aluminium

Guidance for aluminium is being considered and will be included as a technical addendum.

4.2 Treatment grading

Three treatment grades are described in this guideline: T1, T2 and T3. These grades are primarily based on satisfying three main criteria (see Table 3):

- the adoption of a prescribed treatment process with minimum performance criteria (for example temperature/time);
- microbiological limits to demonstrate that the defined treatment processes are operating effectively; and
- measures for controlling bacterial regrowth, vector attraction (for example insects, birds, vermin) and generation of nuisance odours.

In situations where a proponent wishes to use a treatment process that is not prescribed within Table 3, classification is based on either:

(i) the process undertaking a verification program to enable inclusion as a 'prescribed' treatment for the relevant grade; or

(ii) a relatively intensive batch testing program on the produced biosolids to demonstrate pathogen removal.

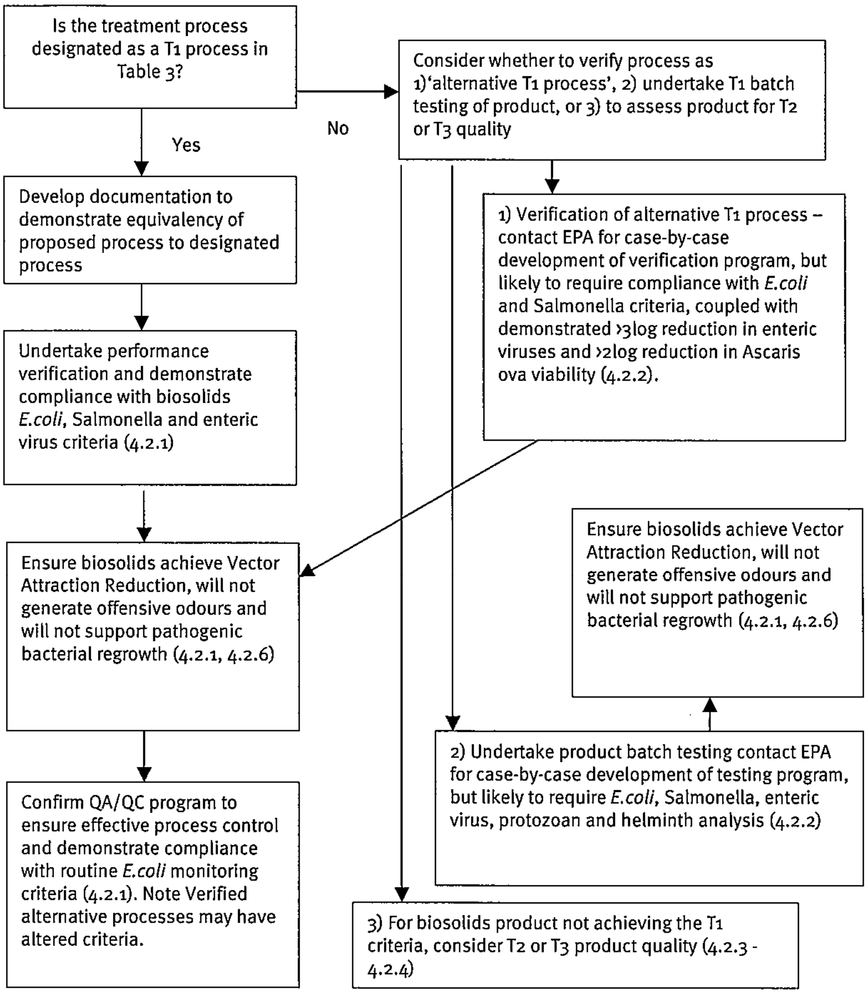
A flow diagram of the treatment classification process using T1 biosolids as an example is provided in Figure 1.

4.2.1 Producing T1 from recognised treatment processes

Grade T1 represents the highest quality grade and from a microbiological perspective is suitable for unrestricted use. Since this guideline does not include regulatory controls on the end use of T1 products, there is a particular emphasis on ensuring adoption of treatment processes that can reliably

BIOSOLIDS LAND APPLICATION

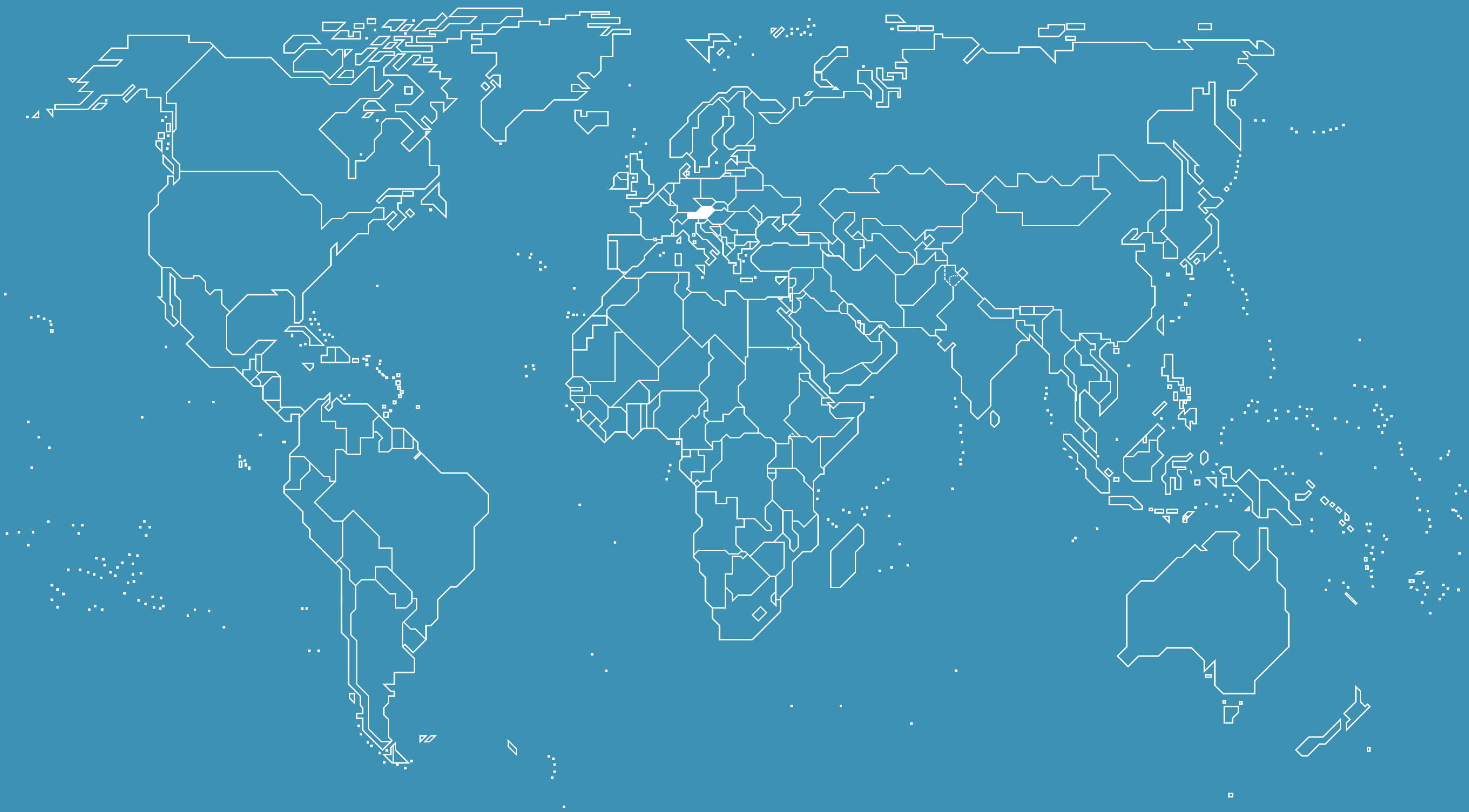
Figure 1. Flow diagram of classification sequence for Grade T1 biosolids



Guidelines for Environmental Management

Table 3. Treatment grades based on treatment process, microbiological criteria and other suggested controls

Treatment process	Associated controls
Treatment Grade T1 Microbiological criteria ***Verification*** (of prescribed processes listed below) < 1 Salmonella/50g (dw), <100 *E.coli* MPN/g (dw) and ≤1 enteric virus PFU/100g with analysis detailed in 4.2.1. Verification of inhibition of pathogen regrowth is also required (4.2.1). ***Routine monitoring*** (of prescribed processes listed below) is based on <100 *E.coli* MPN/g (dw) (4.2.1). ***Alternative process*** microbiological verification described on case-by-case basis (detailed 4.2.2) Vector attraction reduction controls also required (see Table 4).	
Composting processes that simultaneously heat all material (e.g. in-vessel) Temperature of all compost material to be maintained at ≥55°C for ≥3 continuous days with process control as per AS-4454.	Relevant vector attraction reduction controls (refer Table 4) and production of product that does not generate offensive odours. Weed seed controls may be needed in landscaping or agricultural applications.
Composting windrow method Temperature of compost material maintained at ≥55°C for ≥15 days, including 5 turnings of the windrow. Process control as per AS-4454.	Relevant vector attraction reduction controls (refer Table 4) and production of product that does not generate offensive odours. Weed seed controls may be needed in landscaping or agricultural applications.
High pH and high temperatures Biosolids pH raised to ≥12 for ≥72 continuous hours and during this period, maintained at ≥52°C for ≥12 continuous hours. Final biosolids product to be air-dried to a solids content of ≥50%.	Relevant vector attraction reduction controls (refer Table 4) and production of product that does not generate offensive odours.
Heating and drying Biosolids dried by heating particles to ≥80°C to a final solids content of ≥90%.	Relevant vector attraction reduction controls (refer Table 4) and production of product that does not generate offensive odours.
Long-term storage Sludge is digested, dewatered to >10% w/w solids and stored for > 3 years.	Product must be stored in manner that ensures no recontamination and not generate offensive odours.
Thermophilic digestion processes EPA endorsement of processes operating at greater than 55°C will be considered on a case-by-case basis depending on retention time, process stages and batch versus continuous feed/draw.	Relevant vector attraction reduction controls (refer Table 4) and production of product that does not generate offensive odours.



Austria

Austria: Overview

In Austria, waste water treatment as well as sewage sludge disposal is generally a local responsibility. There is a legal basis for the communities to create regional authorities that take over this responsibility. This is a very common solution in Austria, especially in those regions (valleys) where the transfer of the waste water of several communities to one central treatment plant results in the least total costs. Communities can also transfer their responsibility to private companies but this has little relevance in Austria up to now.

SELECTION OF DISPOSAL PRACTICE

Sludge disposal represents an important cost factor for treatment plant operation. For the larger plants (~100.000 p.e.), about 40 to 50% of the operating costs are related to sludge handling and disposal, where the disposal costs are dominating. An Austrian benchmarking system comprising about 40% of the overall treatment plant capacity shows that the benchmarks for operating costs are in the range of €4 to €5 per population equivalent (110g COD/d as yearly mean real pollution load) at total operating costs of about €10 /p.e./a.

The development of sludge disposal methods in Austria is also strongly influenced by the legal prescription for the use of sludge or compost on agricultural land and changes in agricultural practice caused by linking subsidy distribution and product quality requirements (organic farming, eco labelling, and retailer requirements) to the application of sewage sludge and compost on agricultural land. For national agriculture, the economic value of sewage sludge as fertilizer and organic material has nearly no relevance (see attached publication). On a local scale for farmers using sludge, it can be a quite relevant factor. The legal prescriptions and the restrictions for use of sludge and compost for land reclamation or landscaping are much less stringent; therefore an increasing part of sewage sludge is used for this purpose. This development is also favoured by private companies competing on the market taking care of sludge disposal, in cases of moist dewatered stabilized sludge.

As sludge disposal on landfill sites has been legally banned since 2004 this disposal option does not play a relevant role anymore in Austria.

Sludge incineration has increased during the last 10 years, but the overall capacity is still dominated by the raw sludge fluidized bed incineration plant on site of the Vienna Main Treatment Plant with an actual mean pollution load of ~ 3,2 Mio p.e. This plant is combined with a hazardous waste incineration rotary drum kiln and incinerates about 25% of the total sewage sludge production in Austria. This plant is operated by a mainly publicly owned private company responsible also for waste incineration and district heating in Vienna.

During the last 10 years, waste incineration capacity in Austria has markedly increased. In most of the cases sludge is co-incinerated with other wastes, in coal-fired power plants and cement kilns. Co-incineration actually results in lower costs than mono-incineration.

The actual discussion on sludge disposal is dominated by two aspects: soil and food protection from potentially hazardous organic micro-pollutants and sustainable phosphorus management. In Austria there is general requirement for treatment plants > 1000 p.e. for P-removal which results in a ~80 to 85% transfer of P from waste water to sewage sludge. The P-load in sewage sludge can replace up to ~40% of P-market fertilizer imports to Austria, a country that has no P-ore reserves. The first aspect favours incineration as organic pollutants are destroyed. The second favours sludge application in agriculture as this is the least-cost solution for recycling phosphorus and favours mono-incineration of sewage sludge with P-recovery from the ashes. It does not favour co-incineration with cement coal and wastes as it interferes with P-recovery.

The actual situation for sewage sludge disposal in Austria (based on dry solids load) is the following:

- ≤15% is used in agriculture according to the legal requirements (quality control, documentation) and practice described in the Austrian Guideline 17 from the Austrian Water and Waste Association. These legal requirements differ from federal state to federal state. Two of the 9 federal states have banned sewage sludge application in agriculture. Where it is allowed the sludge has to be stabilized and in most of the cases sludge is used after dewatering. At the treatment plant up to a half-year storage capacity is necessary to fulfil the requirement that sludge must not be applied during late autumn and winter. In most cases sludge application is well included in the farm's fertilizer management plans. Direct application of sewage sludge on grass land has little relevance today in Austria. Where hygienic requirements have to be met, composting together with organic support material is the dominant treatment process used to achieve the required quality criteria.
- ~35% is incinerated, the ashes are disposed off at landfill sites
- >50% is used on land after different treatment processes, mainly after composting for application in landscaping, soil remediation, gardening etc. and are probably also exported to some extent by private waste management companies.

In recent years, there is an increase of sludge-drying facilities with different processes (drum dryers, solar drying in glass houses) to reduce storage volume and transport load. On a national scale this still has low relevance. There is also an increase in the introduction of external organic wastes into anaerobic sludge digestion to increase biogas production. Sludge disposal load therefore increases too.

THE BENCHMARK SLUDGE

Table 1 shows the comparison of the Atlas benchmark sludge and the Austrian situation regarding sludge quality.

Table 1. Comparison of the Atlas benchmark sludge and the Austrian situation regarding sludge quality

		Typical Austrian values	
Benchmark sludge Atlas		**50%ile**	**90%ile**
Dry solids	6%w/w	20 to 40 (after dewatering)	
Organic matter	75%w/w	50% after stabilization	
Zinc	1000mg/kg	900	1400
Copper	500mg/kg	200	320
Nickel	40mg/kg	25	45
Mercury	3mg/kg	0,8	2,9
Cadmium	3mg/kg	1,3	2,2
Lead	200mg/kg	55	110
Total nitrogen	3.5%w/w	1,5 – 6	
P2O5	3.5%w/w	5 – 8	
K2O	0.2%w/w	0,3 – 0,7	

From this table it can be concluded that sewage sludge in Austria is normally in compliance with the benchmark, especially for hazardous heavy metals Cd, Hg and Pb. For agricultural application in Austria, only well stabilized sludges are allowed, which results in about 50% organic fraction. Most of the sludge reaching soils is dewatered before treatment and disposal. Liquid sludge application is restricted to a small number of very small treatment plants (<2000 p.e.).

Table 2 shows a comparison of the "benchmark soil concentrations" of the global Atlas and median Austrian values (20cm upper layer), the variation of the Austrian values is in the range of 1 order of magnitude. This information might be of interest.

Table 2. Comparison of the "benchmark soil concentrations"

	Global Atlas Benchmark	Austrian median values
Zinc	40mg/kg	77
Copper	10mg/kg	21
Nickel	15mg/kg	23
Mercury	0.05mg/kg	0,17
Cadmium	0.1mg/kg	0,23
Lead	20mg/kg	19
pH	6.5	

Examples of effective sludge treatment processes in Austria

Stabilisation

- Mesophilic anaerobic digestion (>50.000 p.e.)
- Thermophilic aerobic digestion (rare cases, small treatment plants)
- Separate aerobic digestion (cold) (<50.000 p.e.)
- Simultaneous aerobic digestion common for small treatment plants (<20.000 p.e.)
- (Lime stabilisation)
- Incineration

Dewatering

- Filter presses (conditioning with $FeCl_3$ and lime or poly-electrolytes)
- Belt filter presses (conditioning with poly-electrolytes)
- Centrifuges (conditioning with poly-electrolytes)

Pathogenic decontamination

- Sludge pasteurisation before or after mesophilic anaerobic digestion
- Thermophilic aerobic digestion
- Composting (two step processes, second step windrow)
- Addition of quick lime CaO to dewatered sludge (pH ~12)

ECONOMIC INFORMATION

- Typical proportion of sewage operation costs attributable to sludge (WWTP 100,000 PE): €5 to €10/p.e./year, i.e. 40 to 50% of the operating cost of the treatment plants, 20 to 30% of the capital costs. 5 to 10% of the waste water fee (sewerage and treatment) representing the total (operation and capital) cost for the whole waste water infrastructure.
- Charge to customers for treating 1 m^3 of used (drinking) water is €1 to €2 (based on drinking water consumption), this results in yearly costs of about €45 to €80/inhabitant and year, assuming a mean drinking water consumption of ~130 liters/person and day. There are also other methods for the calculation of waste water fees in Austria but they result in similar fees as a mean. As the typical yearly mean waste water flow in larger cities is in the range of 70-80 m^3/p.e. (including wet weather flow) the costs for the treatment of one m^3 of waste water is in the range of €0,7 to €1. This calculation shows that the comparison of specific costs for treatment of 1 m^3 of waste water does not make sense, as the specific waste water flow per customer can vary in a very broad range (from <100 to >400 l/inhabitant and day).
- 100 litres of diesel fuel: about €130 at public pumps.
- One kilowatt hour electricity: about €0,12 (at treatment plants even €0,08).

SLUDGE DISPOSAL OPTIONS IN AUSTRIA (SUMMARY)

Landfill

At present only material meeting the following important criteria is allowed for landfill disposal:

- Less than 5 % TOC related to total dry solids
- Less than 6000 MJ/kg dry solids.

These criteria cannot be met by conventional sludge treatment and stabilization processes. Only the ashes after incineration (coke after pyrolysis) are meeting these requirements.

Energy recovery

Under waste legislation, energy recovery from sewage sludge has a lower priority as compared to nutrient and organic material recycling. But as the actual political discussion on sludge treatment and disposal is increasingly focussing on possible risks for soil and food due to application of sewage sludge containing organic micro-pollutants in agriculture, public acceptance of incineration is increasing.

Use in forest or woodland

The use of sludge in forests in Austria is forbidden by law.

Use on conservation land or recreational land

This method is of no relevance in Austria.

Use on land reclamation

There are no special regulations for the use of sludge in land reclamation and other possibilities of reuse on non-agricultural land. Approval is necessary in every case. The importance of this option increases especially where the agricultural reuse is no longer accepted. Composting techniques are increasingly used for pathogen removal if required. Areas of application for compost or artificial soils made from sewage sludge include covering landfill sites, recultivation of construction sites for buildings, roads and railroads, and others.

Production of by-products

Some products containing composted sewage sludge are also marketed as garden mould, but this has only local relevance.

There are only 2 large biological industrial waste water treatment plants (each about 1 Mio p.e.) where the sludge has been registered as fertilizer. In both cases, no domestic waste water enters the treatment plant. The sludges are subject to thermal drying after dewatering before they are marketed.

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Ecological and economical relevance of sludge treatment and disposal options

Abstract: Solutions for sludge treatment and disposal produced at waste water treatment plants have to be reliable at any time and therefore need a legally, organisationally and technically sound background. The legal background normally is created at a national or even supranational (EU) level. The technical and organisational solutions can be manifold depending on the specific local situation at a treatment plant. This paper deals with the development of indicators for sludge treatment and disposal that enable the decision makers at a national level to assess sludge disposal options in regard to economic and ecological relevance. Special emphasis is given to the use of sludge in agriculture as it follows the ideas of recycling of valuable nutrients from waste water to agriculture.

This investigation shows the different relevance of sludge disposal for the treatment plant operators and for agriculture in terms of economy and reliability. For treatment plants, sludge disposal represents a very important cost factor, much less for the "consumers" of waste water services. For agriculture, sludge is of low economic relevance while for a farmer using sludge as P-fertiliser it can be high. The most relevant ecological aspect of sludge disposal is with the P-content of sludge, which has a high relevance in regional material cycle while it is low for nitrogen, the value of organic matter in the sludge has only local/regional relevance. The method developed can be applied for other countries. The results for Austria (an EU member state) are calculated and discussed in detail.

Keywords: decision support, sludge treatment and disposal, economic and ecologic indicators

INTRODUCTION

Sewage sludge disposal has always been closely linked to an asymmetric discussion between waste water technology and agriculture. Waste water treatment experts and managers try to convince agriculture that sewage sludge is rich in nutrients and other valuable compounds and praise the idea of nutrient recycling by agricultural sludge utilization. Farmers, and especially the political representatives of farmers' unions, do not deny the arguments of the waste water experts but claim that there is no need to use sludge as it does not increase their income even though they admit that some farmers could make profit from it. The primary interest of treatment plant operators is to have a reliable sludge disposal route at any time and at reasonable cost. They have very little influence on sludge production as it is primarily the consequence of fulfilling a legal requirement (KROISS 2004). Farmers are interested in stabilizing and increasing their income from crop and animal production, to achieve a good price for their products and to maintain soil fertility over long periods of time.

The main argument in favour of banning agricultural use of sewage sludge on land is its contamination with potentially hazardous compounds. The sources of these compounds are manifold and reflect our life-style. Micro-pollutants reach the waste water via our nutrition, our use of pharmaceuticals, personal care products and household chemicals and finally via diffused sources as building materials (heavy metals), road erosion and car traffic. Air pollution, too, contributes to the trace pollution of waste water and hence sewage sludge. Air pollution reaches agricultural land also via dry or wet deposition. Even "best agricultural practice" does not prohibit soil "contamination" by the use of chemicals (pesticides, herbicides, etc.) market fertilizers, fodder, manure (nutrients, pharmaceuticals, disinfectants, heavy metals) and organic material (compost, peat).

Also private waste management companies competing on the market take care of sludge disposal. At an increasing number of treatment plants, sludge disposal is contracted with these companies. They have developed markets for products (compost, "soil", landscaping materials), operate waste incineration plant or cooperate with cement or building material producers. With these products, sludge compounds reach natural soils, landfill disposal or construction sites. Therefore stringent quality control and risk management are necessary to protect consumers and the environment. These new sludge stakeholders have an interest in good relations with treatment plant operators, farmers and other users of their products to meet their commercial goals.

The discussion of an adequate quality of sewage sludge for agricultural application has led to tremendous improvement of sludge quality by strict source control of heavy metals and industrial and trade effluents and by the ban of such materials as cadmium as corrosion inhibitors. E.g., the concentrations of the most toxic heavy metals, such as mercury, cadmium and lead, have dramatically decreased during the last 3 decades and today are close to or even below soil standard concentrations. Wherever strict source control of micro-pollutants is applied their concentrations in the sludge are quite similar and low. The risk management strategy behind the 1986 Sludge Directive was extensive research on the causal relationship between sludge application and the response of soil, plants and crop quality with a mid-term perspective allowing modification if new findings suggest changes.

An application of 1 – 2.5 t DS/ha/a can cover the phosphorus requirements of agricultural production depending on P removal requirements. The dilution of the sludge with the soil material is in the order of 1:10 000. As a consequence changes in soil composition caused by the use of sludge can only be proved by analytical methods after a decade or more of sludge application. Risk assessment, therefore, cannot be based on monitoring data alone and there will be always an unknown risk left. In order to enhance agricultural sludge application, a kind of assurance system was developed, e.g. in Germany, based on a liability fund fed by producers of sewage sludge able to compensate even for unknown risks caused by sludge application. Today the greatest economic risk for farmers using sludge is not with reduced crop quality but with the marketing argument that crops grown without sludge are of better quality and therefore yield higher prices on the market.

Sludge disposal options can also be discussed using the following precautionary criteria:

- no accumulation of conservative compounds (heavy metals, organic micro-pollutants) in soils, plants and crops;

- material input to soils and output have to be equal;
- no observable effect for soil biocoenosis, crops and their consumers,
- no deterioration of ground water quality.

These criteria can only be applied using models describing all inputs and outputs to and from the soil as well as all transformation processes. Such models contain important uncertainties and it is very difficult to asses the associated risk. As a consequence of the situation described above, a rational decision as to whether sludge application on land according to "best practice" is good or bad cannot be expected. This favours incineration or other processes with similar effect as the most reliable solution for sludge treatment and disposal of the ashes.

The following article tries to show that the problem of sludge disposal is often overestimated in terms of ecological and economic relevance, at least on a national level and even more on the EU level. It is the goal to develop a methodology and several indicators to allow decision makers to assess the relevance of the sludge disposal problem in connection with agriculture on a national level.

REFERENCE VALUES FOR QUALITY AND QUANTITY DATA

In order to make data comparable between different locations and on a different time scale it is essential to find reference values. For waste water and sludge it is reasonable to relate data on waste water pollution load and sludge production to the inhabitants connected to waste water treatment plants. The data are also only comparable if they are related to the same unit interval (1 day, 1 year). Also industry and trade discharging their waste water to municipal sewer systems are contributing to pollution load and sludge production at municipal waste water treatment plants. One person (inhabitant) connected to a treatment plant causes a pollution load of 60 g BOD_5/d, which is an internationally agreed standard value for developed countries. The BOD_5 load coming from industry and trade discharges can be converted in to so called population equivalents (PE) by dividing their BOD load in g/d by 60g/d.

The ratio between the total pollution load in the influent of a treatment plant expressed in PE and the number of inhabitants (p) ranges from 1 (small communities without industry) to more than 2 (larger cities). Data on the actual BOD_5- loading of all Austrian treatment plants show an average value of ~2 PE/p.

The area used for agricultural production can be used as a reference for national agriculture. This area can be related to the inhabitants if it is sufficient to nourish its population. The dosage of sludge is normally related to the area of one hectare and the same holds for fertiliser application, crop yields etc. In this report 1 ha of agricultural land is used as reference value. In Austria there are ~4 Mio ha of agricultural land which is 0.5 ha per inhabitant, or 2 inhabitants can be supplied with food per hectare. In Austria agricultural production approximately corresponds to the national food and feed consumption. This assumption is acceptable for rough calculations.

One year is chosen as a reference period. For agriculture as well as for waste water treatment one year comprises all the seasons and is a suitable period for mass balances.

Energy considerations are related to the primary energy consumption per inhabitant (p). Entropy level is not considered because it would significantly complicate the considerations. In central Europe (D, F, A) the average primary energy consumption is in the range of ~50 MWh/p/year which corresponds to a mean power consumption of 6 kW/p.

Relevance of organic matter (dry solids) in sewage sludge

Fifty to 60% of DS in the sludge is organic matter. It represents the largest valuable mass fraction of the dry solids. Sludge composting reduces this fraction. Maintenance of a good soil structure requires organic matter. The amount depends on the local climatic conditions and the crops cultivated. At Austrian climatic conditions about 2 t oDS/ha/year are needed.

Table 1. Relevance of organic matter (dry solids in sewage sludge, situation in Austria)

Daily production of organic dry matter (oDS) in sewage sludge	10-15 kg oDS/PE/year
Production of organic dry matter (oDS), (2 PE per inh.)	~20 kg oDS/p/year
Need of organic matter for soils in Austrian climate	~2000 kg oDS/ha/year
oDS-potential of the sewage sludge to cover the need for organic matter	40 kg DS/ha/year
Actual oDS-potential	~2%

The actual potential is < 1% as only 90% of the population is connected to central treatment plants, part of the sludge is composted before land application, about 15% are put to landfill after biological stabilization and ~ 37 % of the sludge is incinerated. Consequently organic matter for soil stabilisation has to be produced by agriculture; sludge can only be relevant to cover local deficiencies.

Relevance of sewage sludge nitrogen compounds in agriculture

Nitrogen is an unlimited resource. Market N-fertiliser production needs energy (10 kWh/kgN). Sludge normally contains less than 20% of the nitrogen load in the waste water (Table 2). If nitrogen recycling is aimed at, urine separation (as suggested by e.g. GUJER, OTTERPOHL) is more favourable. Urine has a maximum potential of substituting about 55% of waste water N-load (~ 2.2 kgN/p/year) of market N-fertiliser, corresponding to an energy saving of ≤ 22 kWh/p/year or ~3 W/p. This is close to the energy consumption of modern nutrient removal treatment plants with sludge digestion and the use of the biogas for electric power production (NOWAK, 2003).

The Austrian loss of nitrogen compounds via surface waters is ~90.000 tN/year (ZESSNER 1999). This is the same order of magnitude as market fertiliser application. N-losses in agriculture are 6- to 10-fold higher than in the waste water systems.

Table 2. Relevance of sewage sludge nitrogen compounds in agriculture

Average N-load in waste water of household	4 kg N/p/year
N-load in raw sludge	≤ 40% of influent load
N-load in sludge after stabilization	≤ 20% of influent load
N-load in municipal waste water in Austria	6 kg N/p/year
Contribution of industry and trade	30%
Basic requirement for N-removal (WWTP's > 5000)	70%
Export of N via surface waters in Austria	90,000 t N/year
Consumption of market fertilizer in Austria	120,000 t N/year
Average N-load potential collected in stabilized sludge in Austria (8 Mio inhabitants)	8,000 t N/year = ~6% of market fertilizer consumption
Potential of stab. sludge to cover market fertilizer consumption	About 7%

Relevance of sewage sludge phosphorus compounds in agriculture

It is estimated that the economically relevant global phosphorus ore reserves will be exhausted within a period of 75 to several hundred years, depending on the assumptions made. Therefore P can be regarded as a limited resource As phosphorus fertiliser is vital for the food supply of the still growing global population and cannot be substituted, reasonable P-management will be necessary in the future. Requirements for P-removal at treatment plants therefore are not only relevant for eutrophication abatement but also for P recovery.

Table 3. Relevance of sewage sludge phosphorus compounds in agriculture in Austria

Anthropogenic P discharge to waste waters from households	0.7 kg P/p/year
P-load contained in sewage sludge	0.4-1.5 kg P/p/year
P-load in municipal waste water in Austria	1.1 kg P/p/year
Contribution of industry and trade	40%
Requirements fro P-removal	(1-0.5 mg P/l in effluent)
P-load of sewage sludge	0.9 kg P/p/year
Potential of P-load of sewage sludge (8 Mio. inh.)	7,200 t P/year
Consumption of market fertilizer in Austria	18,000 t P/year
Pot. of sewage sludge to cover market fertilizer consumption	about 40%
Loss of P via surface waters	7,000 t P/year
Recommended long term sludge application	1 t DS/ha/year
Required area in Austria, if all sludge is used	10% of agricultural area

One person discharges about 2g P/day into waste water, i.e. 0.7 kgP/p/year. Industry and trade additionally contribute to the P-load reaching municipal treatment plants. P load in sewage sludge can vary in a broad range from about 0.4 to 1.5 kg P/p/year depending on P-removal standards and the use of phosphate-free detergents. Attempts to recover "clean" P from sewage sludge have not been successful so far in regard to cost efficiency (ROELEVELD et.al. 2004), P recycling can be achieved by sludge application in agriculture. Incineration with mono landfill results in P-stocks with high P-concentrations (up to ~6% P, ~14% P_2O_5) for future generations. Plant availability of phosphorus in sludge (or in ash) is strongly dependant on treatment processes applied, and has to be considered if applied in agriculture.

In Austria P-free detergents prevail and there is a P-removal standard (0.5 to 1 mgTP/l) for all treatment plants >1000 PE. If P fertilisation is reduced to the minimum requirement in agriculture, sludge could substitute ~40% of P-market fertiliser imports. This potential could become very relevant for future P-management in Austria. In Austria, a long-term average sludge application of about 1t DS/ha/year is recommended (OEWAV 2004). Table 3 shows that the loss of phosphorus via the surface waters in Austria is nearly equal to the phosphorus transferred to sewage. From the sustainability point of view P in sewage sludge is relevant.

Relevance of sludge transport

The sludge transport load mainly depends on the water associated with the solids and varies from ~10 to 500 kg/p/year. Transport distance and load determine the energy consumption for transport. Even sludge transport seems to have low relevance in developed countries it can have a relevant impact on a local or regional scale and for comparing different sludge disposal solutions.

Table 4. Relevance of sludge transport

Yearly sludge production (after stabilisation)	~20 kg DS/PE
Transport load, thickened liquid sludge, DS content of 4%	~500 kg/PE/year
Transport load, dewatered sludge	60-80 kg/PE/year
Transport load, dried sludge	20-25 kg/PE/year
Transport load, after incineration	7-10 kg/PE/year
Transport volume in agriculture without sludge	10 t/ha/year
Transport volume resulting from urban materials management	7 t/p/year
Sludge production in Austria	~40 kg DS/p/year
Transport volume for sludge in Austria (if all the sludge would be applied in agriculture)	~150 kg/p/year = ~0.15 t/p/year
Total transport volume in Austria (2p/ha)	10/2+7 = 12 t/p/year
Contribution of sludge transport to total transport volume in Austria	0.15:12 = 0.013 (~1%)

Relevance of energy contents in sewage sludge

Table 5 shows the total energy content of waste water pollution and the sludge related to p and PE. The calculations are based on a COD/BOD ratio of 110/60. As mentioned above Table 5 does not reflect entropy i.e. the value of energy recovery, which is highest in methane from sludge digestion and is lowest in waste water. The influence of the water content of the sludge on energy recovery is also not considered. The same is true with the thermal energy contained in waste water.

It can be concluded from Table 5 that sludge treatment and disposal are very relevant for energy management at the treatment plant but will not be relevant for national energy supply in developed countries (<1‰ of primary power consumption). If sludge is incinerated, the value of energy recovery strongly depends on the use of excess heat in district heating systems.

Table 5. Relevance of energy contents in sewage sludge (in Austria)

COD-energy equivalent	14 kJ/gCOD
Pollution of one PE (110 gCOD/p/d)	0.4 kWh/PE/day
Energy contained in raw sludge	≤ 40% (energy in infl.)
Energy contained in stabilised sludge	≤ 25% (energy in infl.)
Energy contained in waste water in Austria (2 PE/p)	0.8 kWh/p/day
Energy potential contained in stabilised sludge in Austria	~8 W/p
Energy contained in stabilised sludge in Austria compared to primary energy consumption (6000 W/p)	8:6000 = 0.0013 = ~1‰

ECONOMIC RELEVANCE OF SEWAGE SLUDGE COMPOUNDS

The following considerations focus also on the differences in costs and benefits for waste water management and agricultural production. The first important difference in regard to economy is the fact that at least in principle agricultural production fulfils a need for the products while sludge production is the necessary by-product of fulfilling a legal requirement. Farmers are free in deciding whether they use market fertilisers or sewage sludge, in many regions there is no need for sludge application as animal production results in enough or even an excess of nutrients in manure.

The monetary value of the sludge can primarily be related to the nutrients nitrogen and phosphorus substituting for mineral fertiliser. For the following considerations it is assumed that all the costs related to transport, distribution on the fields and to the whole administrative work are included in the sludge treatment and disposal costs of the treatment plant. As a consequence the agricultural benefit corresponds to the amount of mineral fertiliser substituted for by sludge application. Actual costs for fertilisers amount to ~€1/kg N and ~€2.3/kg P. Depending on nutrient removal requirements for waste water treatment and sludge stabilisation and dewatering processes the monetary value related to 1 inhabitant (p) can be calculated. These costs can be related to the specific turnover in agriculture and e.g. to the head specific GNP in order to show their relevance.

An Austrian process benchmarking system (KROISS et.al. 2001, LINDTNER 2003) for about 40% of the Austrian treatment plant capacity provided the cost for sludge disposal at the treatment plants in Table 6. It contains real operating costs, the capital costs were calculated from real investment costs updated to the year, a fixed real interest rate of 3%/year and a standardised lifetime for the depreciation of the assets.

Table 6. Economic relevance of sludge disposal for treatment plants (in Austria)

Operating costs for sludge treatment and disposal	45% of total operating costs
larger plants (>50,000)	≥ 5 €/PE/year
smaller plats (<10,000)	≥ 10 €/PE/year
share of disposal only	≥ 85%
Capital costs for treatment and disposal facilities	4-8 €/p/year
Total yearly costs for sludge disposal incl. treatment	8-15 €/p/year = 20% of the total yearly costs for WWTP's

The smaller the plant the higher are the specific costs for sludge disposal. At larger treatment plants the sensitivity of costs regarding disposal options is lower than for small plants. As a consequence, low disposal costs by agricultural use of sludge are especially relevant at small waste water treatment plants.

The estimate of the relevance of sewage sludge for agriculture only considers the monetary value of the total nutrient content potential substituting N and P mineral fertilisers, which might be an optimistic assumption. On the other side, the organic material and other beneficial compounds (e.g. water) are not evaluated. Table 7 shows the nutrient value in comparison to the EU agricultural budget, which was, in 2003, about half of total EU budget, and to the Austrian total agricultural production value The prices for mineral fertilisers vary on a daily basis but this has only little influence on the relations and the conclusions. This investigation also does not reflect the added value created by composting or other transformations of sludge into valuable products.

From Table 7 it can be concluded that agricultural application of all the sludge produced in Austria would have a value of ~0,4% of the production value, while for a farmer using the sludge to completely substitute for the mineral phosphorus requirement, this can result in saving ~4% of his turnover.

Table 7. Economic relevance of sludge for agriculture (farmers) in EU

Agricultural budget of EU, 2003	€ 45 Billion = ~120 €/p/year
Value of sewage sludge, if all inh. would be connected to the sewer system and all of the sludge could be used substituting mineral fertiliser in the EU	1% of EU agricultural budget
Actual value of sewage sludge in the EU (used to substitute mineral fertiliser)	< 0.5% of EU agricultural budget
Monetary value of sludge as fertiliser in Austria per year 0.7 €/kgN 2.3 €/kgP	(1 kg N/p x 0.7) + (0.9 kg P/p x 2.3) = 2.8 €/p/year = 5-10% of operating costs of treatment plants > 50,000 PE
Value of agricultural production in Austria	~6 Billion €/year = 750 €/p/year = 1,500 €/ha/year
Local/regional substitution of whole P requirement	10 kg P/ha/year (23 kgP_2O_5/ha/year)
Monetary value	**31 €/ha/year**
Cost saving for a farmer	**~4% of production value**

SUMMARY AND CONCLUSIONS

Applying the methodology developed in this paper to the actual Austrian situation (~90% of population connected to nutrient removal treatment plants) the following conclusions can be drawn:

- Sludge handling and disposal cause up to ~50% of the costs for waste water treatment, which corresponds to ~ 10 % of the costs (fees) for sanitation.
- The economic value of the valuable compounds of sludge (phosphorus, nitrogen) is ~ €1,5 to €2/inhabitant, or ~4‰ of the yearly turnover in national agriculture if all the sludge would be used on agricultural land to substitute mineral fertiliser. Actually less than 20% is used.

- P removal from waste water (in Austria ~85% of P in waste water is contained in sludge) is relevant for sustainable P management as P content of total sludge production is in the same order of magnitude as the continuous P-loss via surface waters.
- Sludge mono-incineration results in destruction of all organic micro-pollutants and offers the most promising options for P-recycling at large treatment plants as it minimises transport, storage and distribution costs as well as the organic micro-pollutant problem for soils.
- Co-incineration of sludge (cement mills, power stations, etc.) inhibits economical and ecological feasibility of P recycling even it can be an economically feasible solution.
- Direct sludge application of thickened or dewatered sludge on agricultural land is the most economical solution for P-recycling at (small) treatment plants in rural areas.
- The long term environmental risk of agricultural sludge application is low if source control for organic and inorganic pollutants is effective and if good practice is applied (US EPA guidelines, Austrian guidelines, etc.)
- The specific local situation is decisive for the selection of the best solution for sludge disposal.

The Austrian case is typical for an EU member states having fully implemented Urban Waste Water Directive 91/271 with P-removal requirements. If only "normal area" requirements are implemented the fertilising value of sludge markedly decreases, in southern countries the monetary value of the organic matter could become relevant on a local/regional scale.

The basic decision whether sludge should be recycled to agriculture in order to close fertiliser cycles or whether sludge application in agriculture should be banned from a precautionary perspective to prevent hazardous compounds from soil contamination will remain a controversial issue. It seems to be reasonable to "allow" both approaches, depending on the specific local situation taking into account the economic aspect. For both, well developed codes of good practice exist – they include soil and consumer protection for agricultural use and air pollution prevention and safe landfill disposal if sludge is incinerated. From the economic point of view, short-term changes in sludge legislation causing short-term changes in sludge handling and disposal technology are detrimental.

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Wastewater sludge management: A Brazilian approach

Abstract This article presents the main trends for the wastewater sludge management in Brazil. To achieve this, some information about sludge management was used, such as quantitative and qualitative sludge characteristics; legislation, legal references and background; and information about sludge management in some Brazilian states. Based on this information, the main obstacles to its utilization in this area are outlined. Sludge management cannot be understood for sanitation managers as a way to get rid of a problem, but instead, as a way to maximize benefits through its use, carefully considering the environment and sanitary risks, to generate safe and economically viable alternatives that will guarantee the sustainability of the process.

Keywords Brazil; disposal; land use; management; wastewater sludge.

INTRODUCTION

The Brazilian sanitation sector, as is the case in many countries, is facing a number of difficulties in managing residues generated by the water and wastewater treatment plants. Over the last few years, several investments[1] in this sector have been made in order to meet the growing pressures by both society and environmental agencies seeking the protection of the environment, quality of life, and social welfare.

As a result of democratization and implementation of collection systems and treatment processes, a growing volume of complex residues is formed. For this reason, new management and final disposal problems are created. Among these sanitation sector residues, sludge in wastewater treatment plants (WWTPs) is one of the most critical residues due to the volume produced and high management costs (processing and final disposal). It is a very complex process because it demands solutions that, generally, go beyond WWTPs' reach. Nevertheless, most of the time, these actions are essential to fully accomplish the sanitary, environmental, and social results expected from the sanitation company.

In Brazil, these activities have been lately neglected, causing great environmental liability, susceptible to lawsuits and fines by environmental agencies. The series of omissions starts at conception of the treatment systems, which ignores residue management, continues through the environmental licensing agencies during implementation of new companies, and it finally ends up being administered as an emergency, without adequate planning, causing great environmental impact and operational costs. (Pegorini and Andreoli, 2006).

1 *The National Environment Sanitation Secretary estimates R$170 billion is the needed investment to universalize sanitation in the next 20 years*

In this background, this article intends to present the main trends for wastewater sludge management in Brazil. To achieve this, some information about the sludge management was used, such as sludge's quantitative and qualitative characteristics, legislation and legal references/background, and information about sludge management in some Brazilian states. Based on this information, the main obstacles to its utilization in this area are outlined, as well.

WASTEWATER TREATMENT AND SLUDGE PRODUCTION IN BRAZIL

Based on the information from IBGE – Brazilian Institute of Geographic Statistics — the estimated 2005 population for the 5,564 municipalities was 184.1 million. Of this figure, approximately 150.1 million (81.5%) lived in urban areas, while 34 million (18.5%) lived in rural areas.

According to the SNIS – National Sanitation Information System's last publication – there were more than 134 million inhabitants in 2005, 89.3% of the urban Brazilian population. In this research, it was found that the sanitation services supply reaches: 96.3% of this population with domestic water supply, 47.9% with wastewater (sewage) collection, and 31.7% with wastewater treatment.

Based on the numbers presented by SNIS, it is possible to estimate that 64.18 million inhabitants have a wastewater collection system and 42.47 million inhabitants have wastewater treatment systems. In other words, 66% of the collected wastewater is treated.

The SNIS report (2006) also states that, in 2005, about 658 million cubic meters of wastewater were disposed of into the water bodies without proper treatment.

It is important to emphasize that, in most cases, the people that do not have their wastewater collected, manage their own sewage individually by using unitary systems (septic tanks), which in 2005 represented 78 million inhabitants.

MEASURED AND/OR ESTIMATED SLUDGE PRODUCTION

There are only a few studies about the sludge production in Brazil nowadays. Machado (2001) carried out a survey about the sludge production in the Brazilian territory between 2000 and 2001. In his work, 275 water and wastewater treatment plants were analyzed from a total of 984. Tables 1 and 2 show estimates of wastewater sludge production by region and final disposal, respectively.

Table 1. Sludge production by region (2000-2001)

Brazil region	Nº of WWTPs	Wastewater real flow ($m^3.day^{-1}$)	Wastewater project flow ($m^3.day^{-1}$)	Pop. with wastewater treatment (hab)	Informed sludge production* ($ton.year^{-1}$)	Estimated sludge production ($tonTSS.year^{-1}$)
North	03	12,183	56,127	56,000	-	328
Northeast	66	228,056	184,590	1,620,906	-	15,668
Centro-West	66	324,776	505,761	2,025,252	11,385	19,497
Southeast	48	1,033,307	1,445,106	7,286,044	274,719	98,139
South	92	279,294	120,040	1,7889,772	22,529	18,092
Tot. analyzed	275	1,877,616	2,311,624	12,777,974	308,633	151,724

*Source: Machado, 2001. * humid sludge.*

Table 2. Final disposal of produced sludge

Final disposal	Informed quantity* ($t.year^{-1}$)	Informed volume percentage (%)	Estimated quantity ($tSST.year^{-1}$)	Estimated volume percentage (%)
Aterro sanitário	138,418	44.9	75,844	50.0
Agricultura	17,333	5.6	22,973	15.1
Indefinido	152,882	49.5	52,907	34.9
Total analyzed	308,633	-	151,724	-

*Source: Machado, 2001. * humid sludge.*

Considering the population that has access to the WWTP services (approximately 12,777,974 inhabitants) and the value of 33 $gTSS.year^{-1}$, Machado (2001) has estimated a sludge production of 151,724 ton $TSS.year^{-1}$ for a total of 275 WWTP.

According to an essay developed by SNIS in 2005, about 46,836,317 inhabitants have a wastewater collection system (Table 3). Taking into account that the rate among collection and treatment of wastewater is about 66% and the estimated sludge production *per capita* is about 33 g $TSS.year^{-1}$ (Machado, 2001), it is possible to estimate a production of 372,000 ton $TSS.year^{-1}$.

Table 3. Wastewater collected and treated volumes in Brazil for the year 2005

Region	Urban population with wastewater collection	Wastewater volumes: Collected 1,000 $m^3.year^{-1}$	Wastewater volumes: Treated 1,000 $m^3.year^{-1}$
North	270,851	18,952	10,734
Northeast	8,155,166	479,409	438,325
Southeast	29,533,527	1,505,682	946,869
South	4,876,784	243,367	226,283
Center-West	3,999,989	189,725	156,614
Total	46,836,317	2,437,136	1,778,825

Source: SNIS (2006)

According to the Sabesp (Sanitation Company of the State of São Paulo), the eight main WWTPs in the state of São Paulo put together have a production of 528 $ton.day^{-1}$ (humid sludge), which accounts for about 48,000 $ton.year^{-1}$ (dry base).

In the State of Paraná, sludge production has doubled between 1999 and 2003, from 2,000 $m^3.month^{-1}$ to 4,000 $m^3.month^{-1}$. For 2007, assuming that the WWTP has been working with the project flow, it a sludge production of 10,000 $m^3.month^{-1}$ is estimated, which is discarded entirely from the systems.

SLUDGE QUALITY

Physical-chemical and sanitary sludge characteristics

Currently, there are very few wastewater treatment systems that have information about the composition of the sludge produced in their facilities. The survey developed by Machado (2001), for example, pointed to a great uncertainty about the Brazilian average, as shown in Table 4. It is important to note that the wastewater treatment companies located in the South, Southeast and Federal District were the ones that contributed the most information.

Table 4. Mean wastewater sludge composition in Brazil (2000-2001) and Paraná state (2006)

Parameter	Brazil average	Mean deviation	Sanepar anaerobic average [1]	Mean deviation	Sanepar aerobic average [1]	Mean deviation
pH	7,33	2,02	11,6	1,4	12,4	0,4
Conductivity, uS/cm	338,03	534,93	-	-	-	-
(D. M.) Dry material, %	32,12	37,78	57,86	22,6	27,29	5,50
Organic matter, %	56,19	7,96	-	-	-	-
Ashes, %	38,98	9,50	-	-	-	-
Total nitrogen, % N	5,75	8,88	1,07	0,26	1,28	0,9
Total carbon, % C	28,16	6,00	12,56	6,0	4,37	0,5
C/N rate	8,50	3,54	13,32	10,10	1,63	0,40
Total sulphur, % SO_3	0,30	0,25	-	-	-	-
Total phosphorus, % P_2O_5	1,82	1,58	0,26	0,30	0,29	0,50
Potassium, % K_2O	0,36	0,53	0,16	0,10	0,22	0,10
Total calcium, % CaO	4,27	6,55	19,85	8,40	33,66	40,50
Total magnesium, % MgO	0,22	0,20	3,17	3,50	0,43	0,20
Arsenic, mg/kg D.M.	14,69	31,14	-	-	-	-
Cadmium, mg/kg D.M.	10,75	17,69	0,57	0,69	0,27	0,29
Lead, mg/kg D.S.	80,37	95,42	28,99	20,78	17,97	2,96
Copper, mg/kg D.S.	255,39	256,93	73,73	59,01	116,67	18,05
Chromium, mg/kg D.S.	143,72	212,84	28,11	24,69	77,01	50,83
Mercury, mg/kg D.S..	2,35	4,11	0,52	0,50	0,23	0,41
Molybdenum, mg/kg D.S.	112,88	188,08	-	-	-	-
Nickel, mg/kg D.S.	41,99	73,85	18,06	13,14	38,91	12,81
Selenium, mg/kg D.S.	27,24	47,17	-	-	-	-
Zinc, mg/kg D.S.	688,83	814,80	219,49	123,24	458,53	249,01
Fecal coliform, MPN/100g	20.312,67	394.315,24	< 4	-	< 4	-
Fecal streptcocus, MPN	100,00	141,42	-	-	-	-
Salmonella sp, MPN	1,00	1,73	-	-	-	-
Viable helmints eggs, MPN/g	13,47	18,66	<0,02	-	0,03	0,07

Source: Adapted from Machado (2001) and data from Sanepar. Obs.: [1] – After lime addition.

Generally Brazilian WWTPs do not have heavy metal contamination in their sludges. The contamination of sludge was only detected in some isolated cases. That metal contamination is related to unusual contributions from industrial areas.

PROCEDURES AND LEGAL REQUIREMENTS FOR SLUDGE UTILIZATION AND FINAL DISPOSAL FOR SOME STATES IN BRAZIL

Recently, Brazilian Federal legislation has changed the criteria and procedures that define the use of wastewater sludge in agricultural areas, with the purpose of bringing benefits to plantation areas and avoiding the risks for human health and the environment. This new rules are in the 375 resolution from August 29th, 2006, and were established by the National Council of the Environment (Conama). They defined seven processes for reduction in the vectors attraction. Among these processes are anaerobic digestion, aerobic digestion, composting, chemical stabilization, drying and soil incorporation. This resolution also presents another eleven processes for pathogenic agent reduction, with six processes to convert wastewater sludge to class A sludge and five processes to convert it to class B. Also, this resolution establishes an 18-month time period for the Brazilian states to adapt to the new regulations.

The state of Paraná was the first one to publish new legislation adapted to the federal laws. The Environment and Water Resources Agency of the State of Paraná (SEMA) published 001/07 – SEMA, which has the rules that specify the procedures for the use of sludge obtained from wastewater.

The new edition of the legislation established new reference values for heavy metals, as presented in Table 5. The other states have their own legislation, although they have not adapted to the new situation yet.

Table 5. Heavy metals limits according to the legislation

	Maximum sludge concentration (mg/kg, dry base)			
Metals	**Conama 375/2006**	**P4230-CETESB 1999**	**DF 03-07/2006**	**001/07-SEMA – PR**
As	41	75	20	41
Ba	1300	-	-	1300
Cd	39	85	26	39
Pb	300	840	500	300
Cu	1500	4300	-	1500
Cr	1000	-	-	1000
Hg	17	57	15	17
Mo	50	75	-	50
Zn	2800	7500	3000	2800
Se	100	-	50	100

As can be seen in Table 5, sludge parameters for the Brazilian states are more permissive than the new federal legislation, so these states will have to make changes within the next 18 months.

The limits in the new federal law and the actual state laws are presented in Table 6 concerning the pathogenic microorganisms presence and limits.

Table 6. Pathogenic microorganisms limits in Brazil and its states

Pathogenic microorganisms	Maximum sludge concentration (mg/kg, dry base) CONAMA 375/2006	P4230-CETESB 1999	DF 03-07/2006	001/07-SEMA – PR
Thermo tolerant coliform	< 10^3 MPN/g TS	< $2x10^6$ MPN/g TS	-	< 10^3 MPN/g TS
Helmint viable eggs	< 0,25 egg/g TS	-	-	< 0,25 egg/g TS
Salmonella	10 g TS	3 MPN/4g TS	-	10 g TS
Virus	< 0,25 UFF/gTS	-	-	< 0,25 UFF/gTS
Protozoa cyst	-	-	<1/4 g TS	-

NATIONWIDE WASTEWATER SLUDGE KNOWLEDGE PRODUCTION

The Brazilian Sanitation Research Program (Prosab) is a public research program that has received financial support from Finep, a public company that finances projects and studies, since 1996.

The Prosab program was created with the purpose of developing and optimizing technologies in water supply, wastewater treatment, and solid residues management. Furtado et al. (2005) presents the basics of the Prosab program:

1. Review of present technological standards, with the objective of allowing the amplification of the sanitation services by establishment of adequate rules that recognize local and regional unique characteristics and different levels of meeting the population needs and preserving and restoring the environment;
2. Pursuit of technology distribution for the public domain
3. Support of participatory processes, creating cooperative research networks to discuss subjects, previously defined. During its evaluation, Prosab received answers from the coordinators of 33 projects out of those that were developed in the three first research phases (1996, 1998, 2001 respectively).

These three research phases represent a total Brazilian government investment of 19 million reais or $9 million, approximately. Table 7 shows information considering the financial resources from FINEP for the development of these research projects, not taking into account human resources fees and scholarships.

Table 7. Information concerning the first three Prosab research phases

Area	Number of projects	Finep resources (x 1,000 U$)**	Scientific production* (1)	Technological production*
Water	12	U$ 2,509.00	51	7
Wastewater	30	U$ 3,931.00	108	32
Sludge	16	U$ 1,845.00	82	16
Solid waste	13	U$ 1,548.00	25	1
Total	71	U$ 9,833.00	266	56

*Source: Adapted from Furtado et al., (2005). * Information about 33 projects from a total of 71 projects. (1) Considering books, congress articles and periodics. **(U.S. dollars).*

Looking at the directly technological production for the sludge issue, in these 33 projects, we can find 3 new products, 4 new processes, and 7 new methodologies, totaling 14 new products. Considering the transfer of technology and its application in full scale, research related to sludge somehow affected 3.5 million people during 2004, mainly due to the use of the proposals by Sanepar – Sanitation company of the state of Paraná

Furtado et al. (2005) states that the research regarding wastewater and sludge has very consistent results. The human capital and material development were significant. The different institutions involved had important information exchange and a good relationship was developed among sponsors, the developers of technology and final users. Concerning scientific publications about wastewater sludge, 13 articles in national conferences, 2 articles in international conferences, 4 book chapters and 6 national books, were produced, aside from theses and dissertations that resulted from these projects.

Several books resulted from the Prosab research program. Up to 2003, the most important book titles about sludge are (original titles are in Portuguese):

- Solid residues from sanitation: Processing and final disposal – Edition 2 / 2001;
- Management and utilization of the wastewater sludge in agriculture – Edition 1 / 1999;
- Practical manual for biosolids composting – Edition 1 / 1999;
- Management of Non-mechanical stabilization lagoons – Edition 1 / 2000;
- General perception of treatment and final disposal of water treatment plant sludge – Edition 1 / 2000;

BRAZILIAN STATES WITH ESTABLISHED SLUDGE MANAGEMENT

São Paulo State sludge management

The State of São Paulo, located in the southeast region of Brazil, is formed by 645 municipalities with a total population of 40 million inhabitants. It is the Brazilian state with the highest population density and the biggest industrial area.

Sabesp, São Paulo's sanitation company, is present in 367 municipalities in this state, and it is responsible for planning, constructing and operating the water, wastewater, and industrial systems.

According to data from SNIS in 2005, the company served 18 million inhabitants with wastewater treatment system. The volume of collected and treated wastewater for that year was 888,607 and 544,961 million cubic meters, respectively.

Santos (2003) states that the main sewage system in the metropolitan area of São Paulo is formed by five integrated systems, with WWTPs: ABC, Barueri, Parque Novo Mundo, São Miguel and Suzano. In the countryside of the state, there are some big WWTPs, such as Franca WWTP (in Franca) and Lavapés WWTP (in São José dos Campos), while in the coastal region the largest system is the Bichoró WWTP (in Mongaguá).

According to Sabesp's information, approximately 90% of the sludge produced in the State of São Paulo is landfilled. The quota used in the agriculture represents approximately 10% of the total generated sludge. The Lavapés WWTP, is about to change its lime stabilization system and will start to use a system that uses composting for sludge treatment.

Table 8 shows the main characteristics of the WWTP of the State of São Paulo as the main alternatives used in stabilization, sanitizing, conditioning, dewatering and final disposal of the sludge produced.

Table 8. Sludge production and adopted processing alternative in the State of São Paulo.

Region	WWTP	Production	System	Stabilization and sanitizing	Conditioning	Dewatering	Final disposal
São Paulo city	ABC	55 ton/day	Activated sludge	Biodigestion lime + ferric chloride	Lime + ferric chloride	Belt press filter	Landfill
	Barueri	220 ton/day	Activated sludge	Biodigestion	Polymer + ferric chloride		
	Parque Novo Mundo	65 ton/day	Activated sludge	Lime + ferric chloride	Lime + ferric chloride		
	São Miguel	30 ton/day	Activated sludge	Biodigestion	Lime + ferric chloride		
	Suzano	45 ton/day	Activated sludge	Biodigestion lime + ferric chloride	Lime + ferric chloride		
Country side	Franca	55 ton/day	Activated sludge	Biodigestion	Polymer + ferric chloride	Belt press	Agriculture
	Lavapés	55 ton/day	Activated sludge	Lime	Lime	Centrifuge	Landfill
Costal	Bichoró	3 ton/day	Activated sludge	Extended aeration	Lime + ferric chloride	Belt press	Agriculture

Obs.: The sludge production volumes are presented in humid base, with solid rate of approximately 25%. The Franca WWTP utilizes WTP sludge addition.
Source: Sabesp (2006).

In order to fulfill requirements of the Environmental Control Company of the State of São Paulo (CETESB), Sabesp developed, in 1988, a Ruling Plan for sludge use and disposition in the metropolitan area of the city of São Paulo. This plan defined two main alternatives for sludge disposition: monofill sites and agriculture use. The use of landfill sites is linked to the sludge's thermal drying, so the volumes to the site would be reduced.

Case study: sludge management in the State of Paraná

The State of Paraná is located in the South of Brazil and it is formed by 399 municipalities, with approximately 10 million inhabitants. According to Sanepar, in 2006, there were 2,722,193 connections to water, and the sewage system had 1,386,966 connections. Currently, the annual sludge production discarded by the WWTP is estimated in 120,000 m^3.

The most important variables in the dewatering process are the sludge characteristics, available area and climatic factors. The sludge drying beds generally produce good results with anaerobic stabilized sludge, easily obtaining 50% of total solids (TS), with the possibility of reaching more than 70% of TS. As for the manual work and climatic factors, however, the results are not satisfactory. Generally, the conditions in the western portion of the State of Paraná fulfill these requirements, which had made it possible to use the sludge drying beds in most of the WWTPs, from small to average scale. Table 9 shows the relation between WWTP scale and the sludge processing alternative used in Paraná.

Table 9. Dewatering process utilized in Sanepar considering the WWTP scale.

WWTP scale	Number of connections	Number of WWTP (2002)	Sludge production (ton TS/year)	Dewatering	Flow (L/s)	Sludge drying bed area*
Small	5,000	109	16 tons	SDB**	50	95 m^2
Medium	5,000 to 20,000	112	16 tons to 320 tons	SDB / Mechanical	50 to 150	1,800 m^2
Large	> 20,000	11	320 tons	Mechanical	> 150	-

** Required area considering 15 kg TS/m^2, drying cycle 30 days (25 + 5 days for cleaning). ** sludge drying beds.*

The main alternative for reduction of pathogenic microorganisms in the sludge produced in the WWTPs in Paraná, is the addition of lime, for pH control, and later controlled agriculture disposition. Sanepar recycles the wastewater sludge using agriculture, according to the control procedures established by The Environmental Institute of the State of Paraná (IAP).

Two good examples that could represent the model of Paranás sludge management are the Belém WWTP (biggest sludge producer in Paraná), with approximately 85 ton/day and 15 to 20% TS, resulting in an estimate of 2,600 ton/year of TS. The other example is the WWTP in Foz do Iguaçu that produces approximately 150 ton ST/year. This sludge is produced by 5 WWTPs and after dewatering in sludge drying beds, it is combined with sanitizing processing, stocking and, final disposition (agriculture).

The wastewater treatment used in the Belém WWTP is the aerobic process with extended oxidation. The sludge removed from the process, which has good stabilization condition, goes to the thickening, conditioning, and mechanical dewatering by the dewatering press and centrifuge. The dewatered sludge is mixed with hydrated lime in dosages of 50% (as TS). The lime is stored in vertical silos equipped with automatic dosage systems. The blend with the sludge is made by mechanical mixer. After the mixing phase, the sludge is transported to the storage yard. The data presented in Table 10 shows the average sludge characteristics for the Belém WWTP.

The agricultural use of the sludge requires an area of about 700 hectare / year. The selection of the area is made by Emater – PR (Institute for Technical Assistance and Rural Extension – Paraná), which also performs the environmental monitoring, through an agreement. Transport is by dump truck. The farmer receives, without charge, the sanitized sludge in the area of application. Emater provides the equipment for application to the land, which is attached to the farmer's tractor.

The medium rate of application is about 8 ton TS/hectare, which varies according to the recommendation for each crop, considering that sludge variability for the same sludge is low. The sludge produced in the Belém WWTP, which has about 15 to 20% of TS, is characterized as semi-solid cake that needs specific equipment for its use. The main crops for which the sludge is used are: corn (54%), oats (4%), turfgrass (30%), fruits (9%), and beans (3%). Table 11 presents the average results observed with the Belém WWTP sludge use in the production of corn.

Table 10. Average sludge characterization for 17 lots from the Belém WWTP after lime addition

Agronomic potential										
Sludge	Total N %	Total P_2O_5 %	K_2O %	C %	C/N	Ca %	Mg %	Org. matter %	pH	Fixed solids
without lime	4,9	3,7	0,36	32,1	6,5	1,6	0,6	69,4	5,9	37,2
50% of Lime	2,9	2,2	0,2	20,5	7,0	9,1	4,8	37,6	12,0	52,5

Sanitary					
Sludge	Total coliform	Salmonella	Helmint eggs	Viable helmint eggs	protozoa cysts
without lime	$7.5x10^8$	17%	429	-	2,4
50% of Lime	-	-	-	0.21	-

Heavy metal (mg/kg ST)							
Sludge	Cd	Ni	Cr	Pb	Zn	Hg	Cu
50% of Lime	1.38	20.64	45.25	34.64	383.96	1.23	85.90

Emater-PR, verified in essays developed in some properties in the municipality of Fazenda Rio Grande (PR), an increase in the productivity from 32% to 54% from 1994 to 1997. These important increases in the productivity observed in these studies make evident the low technological level of these farmers, who generally do not use any products for soil correction or fertilizer. In developed systems of agriculture production, the expected agricultural responses due to the use of sludge are less significant. In these cases, though, the advantage is the reduction of the chemical fertilizers demand, especially nitrogen, aside from physical-chemical and biological improvement of the soil.

Table 11. Corn crops production fertilized with wastewater sludge in comparison with chemical fertilization

Municipality	**Productivity without sludge (kg/ha)**	**Productivity using sludge (kg/ha)**	**variation (%)**	**Absolute variation (kg/ha)**
Balsa Nova	4,465	8,056	+ 80	3,591
Fazenda Rio Grande	8,150	8,700	+ 7	550
	4,750	7,093	+ 49	2,343
	4,925	6,973	+ 42	2,048

The wastewater treatment system in Foz do Iguaçu is made of 5 WWTPs. The wastewater treatment plants use anaerobic process, with systems that are similar to the UASB reactor, which produces a stabilized and thickened sludge. The dewatering is conducted in sludge drying beds, with sludges of higher solid content than those dewatered mechanically, with about 50% of TS. The sludge from these WWTPs is transported to a management sludge unit (UGL), next to the WWTP where it is subjected to the sanitizing, stocking and characterization. In this UGL, the hygienic process used is the addition of quicklime (mix of lime in a rate of 50% to sludge measured as TS). After the mixing process, the sludge is stocked in an appropriate area. The sludge which passed through the sanitizing process presents characteristics as shown in Table 12.

Table 12. Average sludge characterization for Foz do Iguaçu WWTPs after lime addition

Agronomic potential										
Sludge	Total N %	Total P_2O_5 %	K_2O %	C %	C/N	Ca %	Mg %	Org. matter %	pH	Fixed solids
50% of Lime	0.91	0.72	0.05	12.59	13.84	7.76	4.37	-	12.4	-
Sanitary										
Sludge	Total coliform		Salmonella		Helmint eggs		Viable helmint eggs		protozoa cysts	
50% of Lime	< 200		< 200		-		0		-	
Heavy metal (mg/kg ST)										
Sludge	Cd	Ni	Cr	Pb	Zn	Hg	Cu			
50% of Lime	2.5	17.0	37.5	113.0	100.0	< 0.5	40.5			

According to the studies developed in Foz do Iguaçu, the sludge was applied in corn and soy crops in two farmers' properties. The volume of sludge produced in the city is only enough for 15 hectares' area of application per year. The sludge showed humidity of 26% (74% of TS) and solid consistency. Due to its more solid characteristics, it was possible to use the same equipment used to application of lime on the land, commonly found in rural areas, with no need for more sophisticated equipment.

The wastewater sludge, in some cases, may contribute to the soil contamination with heavy metals. These metals in the sludge have their origin in industrial activities. These heavy metals not only have harmful effects on plants, but can also affect soil biochemical processes. Organic matter decomposition, mineralization and nitrification are some of the processes that could be inhibited by heavy metals in contaminated areas (Tsutiya, 2001).

The heavy metals present in the sludge can be divided in two categories, depending on the risk that they represent. Some examples of metals that are considered of low risk are: Mn, Fe, Al, Cr, As, Se, Sb, Pb and Hg. The potentially hazardous metals for humans and animals are: Zn, Cu, Ni, Mo and Cd. Among these metals, some are essential micro nutrients for plants (Cu, Fe, Mn, Mo and Zn), and others have a beneficial effect (Co and Ni). In order to use wastewater sludge in agriculture, great care should be taken when characterizing and evaluating the inflow wastewater and defining limits for some determined substances (Silva et al., 2001; Tsutiya, 2001).

In a study performed in the metropolitan area of Curitiba concerning the use of sludge in agriculture, Pegorini (2002) evaluated heavy metal content in bovine, swine and poultry manure. He found that the concentration of Cu is slightly superior to Cr, Cd, Pb and Ni for the biosolids, as the result of industrial activity. In the case of Zn, the content found in the manure are slightly higher in bovine and poultry manure, but lower in swine manure. So, it can be assumed that the wastewater sludge does not offer greater health risks than the animal manure that is frequently used in farms.

Table 13 presents the distribution results of the different variation ranges considering the maximum values admitted in the IAP rule for agriculture use of wastewater sludge in Paraná for the elements Cu, Ni and Zn. For "class A" sludge in USA – USEPA Se and Pb, also for Pb and Ba related in CONAMA and finally for Cd and Cr in the Brazilian Ministry of Agriculture.

Table 13. Distribution by percentage of the samples, according to the normative references of limits and the average for WWTPs in the State of Paraná

Element	Reference rule	Reference value	Percentage from reference value			
			< 50%	< 80%	< 100%	> 100%
Ba	CONAMA	1,300 ppm	94.87%	98.71%	100.00%	0.00%
Se	USEPA	36 ppm	98.71%	98.71%	98.71%	0.00%
Cd	Agriculture minitry	8 ppm	88.46%	93.59%	93.59%	6.41%
Cr	Agriculture ministry	500 ppm	94.87%	96.15%	98.71%	1.29%
Cu	IAP – PR	1,000 ppm	89.74%	93.59%	96.15%	3.85%
Ni	IAP – PR	300 ppm	89.74%	92.30%	94.87%	5.13%
Pb	CONAMA / USEPA	300 ppm	70.51%	84.61%	93.59%	6.41%
Zn	IAP – PR	2,500 ppm	76.92%	92.30%	93.59%	6.41%

MAIN OBSTACLES FOR THE USE OF WASTEWATER SLUDGE

Currently, the sanitation companies are at a very important point concerning adjustment of their processes for the use of their sludge in agriculture. According to the resolution 375/2006 issued by Conama, sanitation companies had 18 months as of February 2007 to fulfill the new regulations.

One of the greatest difficulties facing the sanitation companies is related to the verification of sludge sanitation concerning the presence of specific viruses and organic micropollutants. This kind of analysis is not performed by most commercial laboratories, as it is restricted to certain types of specific research in universities.

Another important aspect in the process of the use of sludge in agriculture is the integration of many people involved in the processes (sludge generation, processing, stocking, transport, soil incorporation), such as sanitation companies, rural production and technical assistance institutes, environmental control companies, farmers, and people in general.

Due to this demand, there is a great need for integration for technical and operational co-operation among companies, institutions and public administration involved in the process and the support from the farmers who will receive the sludge.

Maintenance and reliability of defined processes are extremely important to reinforce credibility in new implemented programs. This way, the environmental education has essential importance to the proper development of this kind of programs and effectively promotes cultural and behavioral changes.

In this context, it should be emphasized that there is a great need for the changes in the cultural behavior of farmers from small and big properties, authorities, unions, so the access to information can make it possible to give new information to these participants and develop the possibility of constructive discussion about the real possibilities of this alternative. Another important cultural change is about the way people perceive sludge disposition. Whereas it should be seen as an advantage and as a new product, it is usually perceived as a problem that people want to get rid of (Andreoli et al., 2001a).

This way, the WWTPs should be seen as a biosolids industry, not just as way to treat wastewater. Furthermore, the evaluation of a system would not be limited just to the effluent quality, but also to its products' quality, like sludge quantity and characteristics for the residues/products could be sold or supplied.

Even though the beneficial characteristics of sludge in the agriculture are clear, the technical rules for each location should be respected to avoid harmful impacts on the environment. In regions where the area for agriculture is vast, one of the logical alternatives is the use in agriculture

FINAL CONSIDERATIONS

The great production of wastewater sludge in the urban centers and its destination is an environmental problem of extreme importance and represents a great challenge.

The subject's complexity deserves to be outlined in Agenda 21, which, in the 21st chapter, deals specifically with the final disposal of sanitation residues. The recommendation indicates, initially, the measures that aim at the reduction of residue production, followed by alternatives of reusing and recycling, and finally the adoption of measures for final disposal taking the environment into account.

Andreoli and Pegorini (2006) state that the use of wastewater sludge cannot be considered as a simple way for sanitation managers rid themselves of this problem, but that the recycling concept demands adoption of technological alternatives that maximize benefits through the use of beneficial components of the residues, carefully considering the environmental and sanitary risks, to generate safe and economical viable alternatives that will guarantee the sustainability of the process.

Considering the current numbers for urban collection and wastewater treatment services, as well as the increasing legal requirements for magnifying these services for the remainder of the Brazilian population, it is expected that biosolids production will grow in the country.

In spite of the changeable composition, function of regional characteristics and of the processes where they are generated, generally, biosolids contain valuable components, making it possible to use them as input in the agricultural processes. Wastewater sludge contains nutrients, essential elements for the development of plants (macro and microelements), and organic substances, the basis for sustainability of soils, and very few WWTPs in Brazil have sludge contamination by heavy metals.

Currently, despite the Brazilian territorial characteristics offering a great agricultural potential to the country, use of sludge in agriculture is low (about 15% of the wastewater sludge is used in agriculture). According to the available estimates (Machado, 2001) a great amount of the sludge produced in the domestic territory is designated to sanitary landfill sites.

It is valid to point out that the high indexes of the use of this alternative are not able to represent the definite solution for the problem. In Brazil, the available data (IBGE 2007) indicates that only 30.3% of the units of final disposal are sanitary forms of waste management. This means that the great majority of the Brazilian cities (about 73% of the cities present population of up to 20.000 inhabitants) still make the final disposal of its residues through irregular dumps or landfill sites with little environment control.

Another aspect concerns the needed characteristics of biosolids conditioning for final disposal in landfill. As demonstrated in the experience of the State of São Paulo, the use of monofills for sanitation wastes is related to the necessity of draining and drying the sludge. This condition implies the use pf specific equipment to reach operational conditions not only for disposal of the residue but also for the reduction of the volumes to be land filled.

As for the integrated biosolids management, sanitation monofills can be considered as an emergency alternative for cases where the agricultural use of sludge is not possible, either because of restrictions on the quality of sludge (e.g. possible industrial contaminations) or for other administrative and technical reasons (e.g. out of order equipment, contract renewal, adverse environmental conditions for sludge application).

It must be highlighted that a landfill site needs good design to grant its environment protection as well as good maintenance for a long time after being closed. Furthermore landfills do not allow recovery of nutrients from sludge.

Despite the visible benefits of the agricultural use of the wastewater sludge as well as of the natural aptitude of soils for agriculture, this practice still faces obstacles, mainly when considering the logistics involved in the management of the sludge-producing units: sludge cake dewatering and conditioning, quality analysis, storage, transportation, evaluation of the agricultural aptitude of the place and incorporation to the soil (Andreoli et al., 2001b).

Along with alternatives already established for final disposal, several lines of action have been studied as an alternative to the beneficial use of biosolids, among which we can outline: the use in forest plantations (forestry), reestablishment of degraded areas and substratum manufacture for seedlings.

In recent years, Brazil has concentrated operational and scientific efforts for the management of the wastewater sludge produced in the treatment stations, however little attention has been given to the management of septage of *in situ* sanitation systems, such as domestic septic tanks. As mentioned initially, only 47.9 % of the urban populations are served by services of wastewater collection.

From this point of view, due to the lack of guidelines and reliable management techniques and alternatives, either from private initiative or the public sector, septage management is generally not performed correctly. In some regions, the septage is directed to sewage treatment plants, when they exist, that accept this type of residue. The majority of the wastewater produced however, is disposed of without any technical criteria – in the soil, rivers and even as fertilizer in agriculture – risking the population's health and the environment quality.

Having this situation and considering that the state-of-the-art knowledge about septage still needs to be consolidated, Finep (Financier of Studies and Research) through Prosab's Program published a specific research phase for the development of studies covering the different regions of the country. The study that involves five Brazilian research institutions will, initially, develop studies of the septage produced by septic tanks, followed by the evaluation and the development of alternatives of treatment and disposal of this sludge.

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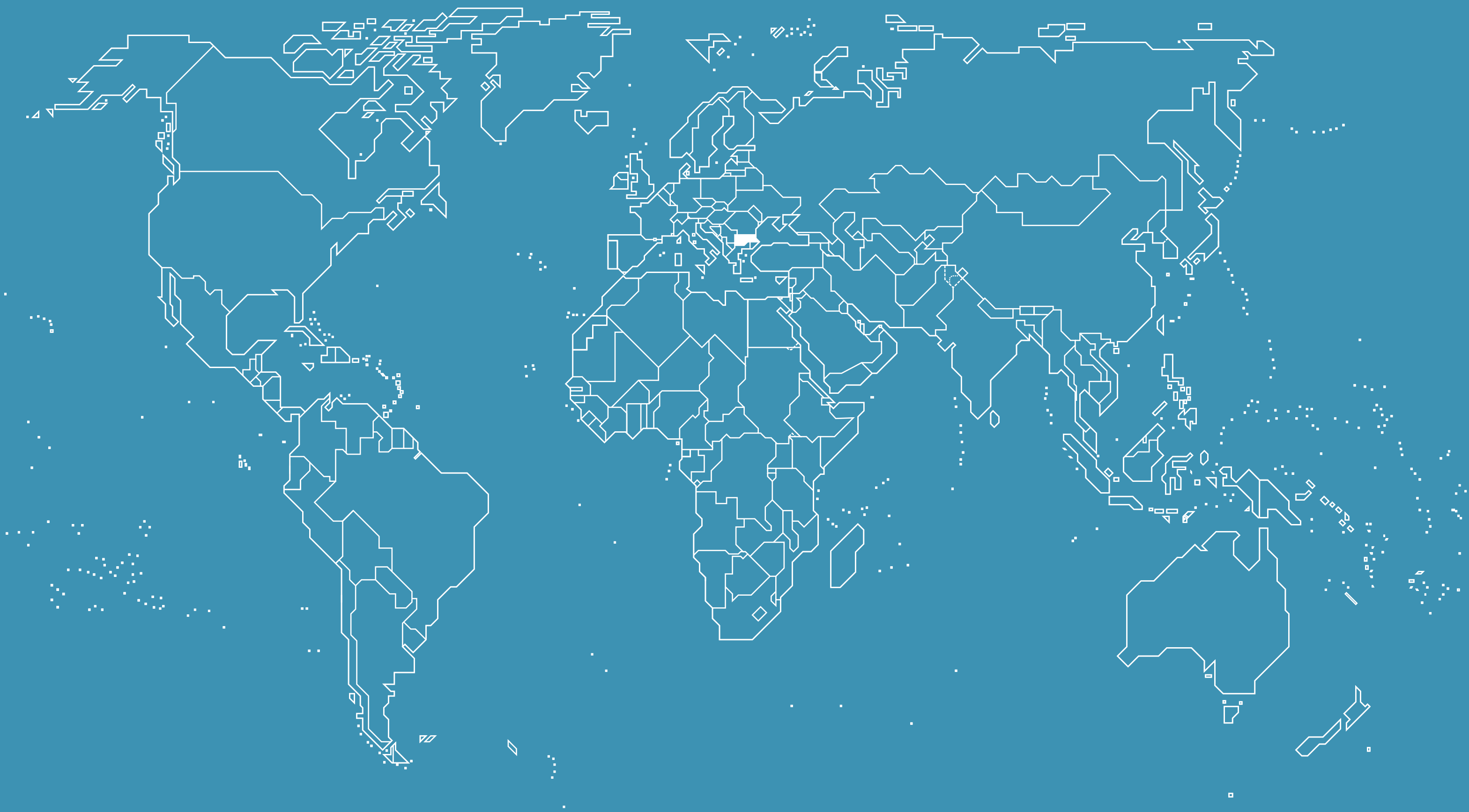

Bulgaria

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Bulgaria

BACKGROUND

In Bulgaria, both the State and the Municipalities are responsible for wastewater treatment and sewage sludge disposal. New legislation is being introduced, under which these activities are likely to be transferred completely to local government.

SELECTION OF DISPOSAL PRACTICE

In most cases, the method of selection of the disposal practice is based on a technical-economic appraisal of available options. Generally, the investor aims to minimize the long-term cost of sewage sludge disposal while meeting increasingly rigid environmental protection criteria.

In practice for benchmark sludge, the available options are limited. Stabilization is necessary for every disposal route in Bulgaria. The limits in heavy metals regulations for sludge use in agriculture have to be considered during the time of application. The same legislation makes no provision about a special regulation on the treatment technologies needed to ensure the covering of the prescribed requirements concerning the sludge quality when utilizing them in the agriculture. However, there is a National Plan developed for WWTPs' sludge removal which states that the first step in the sludge treatment is its mechanical dewatering. The following scenarios are foreseen in this Plan:

- Scenario I. Mechanical sludge dewatering with belt filter presses up to a humidity of 75% – for WWTPs with more than 10 000 population equivalent (PE);
- Scenario II. Stabilization of the mechanically dewatered sludge with hydrated lime while maintaining pH > 12 within at least 12 (or more – 24) hours;
- Scenario III. Anaerobic sludge stabilization (min 15 d at 35 °C) for WWTPs with more than 150 000 PE, for smaller WWTPs Scenario II is to be considered;
- Scenario IV. Incineration of the sludge in fluidized layer furnace for WWTPs with more than 500 000 PE, for smaller WWTPs Scenario III is to be considered.

There are no special regulations for the use of sludge in land reclamation and other possibilities of reuse of non-agricultural land.

Although in the National Programme it is recommended to develop a programme for the utilization of the sludge in agriculture and forestry, as well as for land reclamation, the only option in practice remains disposal at landfills. At present there is no incineration plant for municipal sewage sludge in Bulgaria.

ECONOMIC INFORMATION

Typical proportion of sewage operation costs attributable to sludge (WWTP 100 000 PE): 18% capital, 15-35% running costs, which varies within large rates;

- Charge to customers for treating 1m^3 of waste water: € 0.21;
- 100 litres diesel fuel: about € 0.89;
- 1 kWh of electricity: about € 0.40, but it varies during the day.

LANDFILL OPTION

At present in Bulgaria, the majority of sludge is landfilled. Stabilization of the benchmark sludge is the prerequisite for the landfill option. The most common method of stabilization of sludge from a treatment plant of this size (100 000 PE) is mesophilic anaerobic digestion, while aerobic stabilization is still a rarely used practice. Recently a more often used practice in the case of landfilling is to partition special cells for sludge at the landfills.

INCINERATION OPTION

At present there is no incineration plant for municipal sewage in Bulgaria. A project for incineration of the waste produced in Sofia is in process and if it is eventually constructed, there will be an option for incineration of the sludge produced at the Sofia WWTP as well.

GENERAL AGRICULTURAL SERVICE PRACTICE

There is no practice for utilization of sludge as fertilizers in Bulgaria except for a few cases. Legally this is regulated under permits and monitoring procedures. Similar scenarios are also proposed in the so-called Sludge Management Plans but it is not applied in practice except for a few cases. Since 6th December 2000, the "Ordinance for the requirements for soil protection when utilizing the waste water treatment sludge for agricultural purposes" has been approved and promulgated in Bulgaria. This Ordinance regulates in detail the limits regarding the content of heavy metals in soils and sludge from urban WWTPs when utilizing them as fertilizers, as well as the annual norms for loading the agricultural areas with sludge. (Table 1 and Table 2)

Table 1. Limits on admissible concentrations of heavy metals in sludge meant to be utilized in agriculture

Parameters	Limits on admissible concentrations (LAC) (mg/kg dry solids)
Cadmium	30
Copper	1500
Nickel	300
Lead	1000
Zinc	3000
Mercury	16
Chrome	500
Arsenic	30

Table 2. Limits on admissible quantities (LAQ) of heavy metals that could be introduced annually to agricultural lands, average for ten-year period

Parameters	Limits on admissible quantities (LAQ) (kg/ha/year)
Cadmium	0.15
Copper	12.00
Nickel	3.00
Lead	15.00
Zinc	30.00
Mercury	0.10
Chrome	15.00
Arsenic	0.20

In deference to EU Directive 86/278/EEC, in this Ordinance the limits on admissible concentrations of heavy metals in soils are dependent on the local values of pH (Table No 3) but unfortunately the Ordinance does not regulate the content of pathogenetic microorganisms and substances attractive to insects and rodents, nor are there quantitative sanitary-hygienic parameters that should be achieved as a result of the sludge treatment.

Table 3. Limits on admissible concentrations of heavy metals in the soil (mg/kg dry solids in a representative sample as it is determined for pH from 4 to 7)

		Limits on admissible concentrations (LAC)							
No	pH[1]	Lead	Copper[2]	Zinc	Cadmium	Nickel[2]	Chrome	Mercury	Arsenic
1	4	25	20	30	0.4	25	150	1	25
2	5	40	40	60	0.8	35	170	1	25
3	5.5	50	60	90	1	50	180	1	25
4	6	70	120	200	1.5	60	190	1	25
5	7 and >7	80	140	300	3	70	200	1	25

1. *pH of the soil is determined in suspension consisting of 1 part soil and 2.5 parts distilled water*
2. *The Authorities might allow exceeding of the pointed out values for soils with pH constantly higher than 7. The maximal determined concentration of heavy metals shall not exceed the values for pH=7 with more than 50%.*

Current legislation containing limits on heavy metals relies on the control of the industrial water emissions when discharged indirectly into the sewerage. Scientific studies in this field are dated more than twenty years ago but only at pilot stations.

Use on grazing land

Not in use.

Use on arable land

Not in use except for a few cases.

Domestic use of biosolids

Not in use.

Use in forest or wood land

Not in use.

Use on conservation land or recreational land

Not in use but attempts are made.

Use in land reclamation

Used temporarilly only in a few cases. It is considered in the Sludge Management Plans.

Production of by-products

None are produced.

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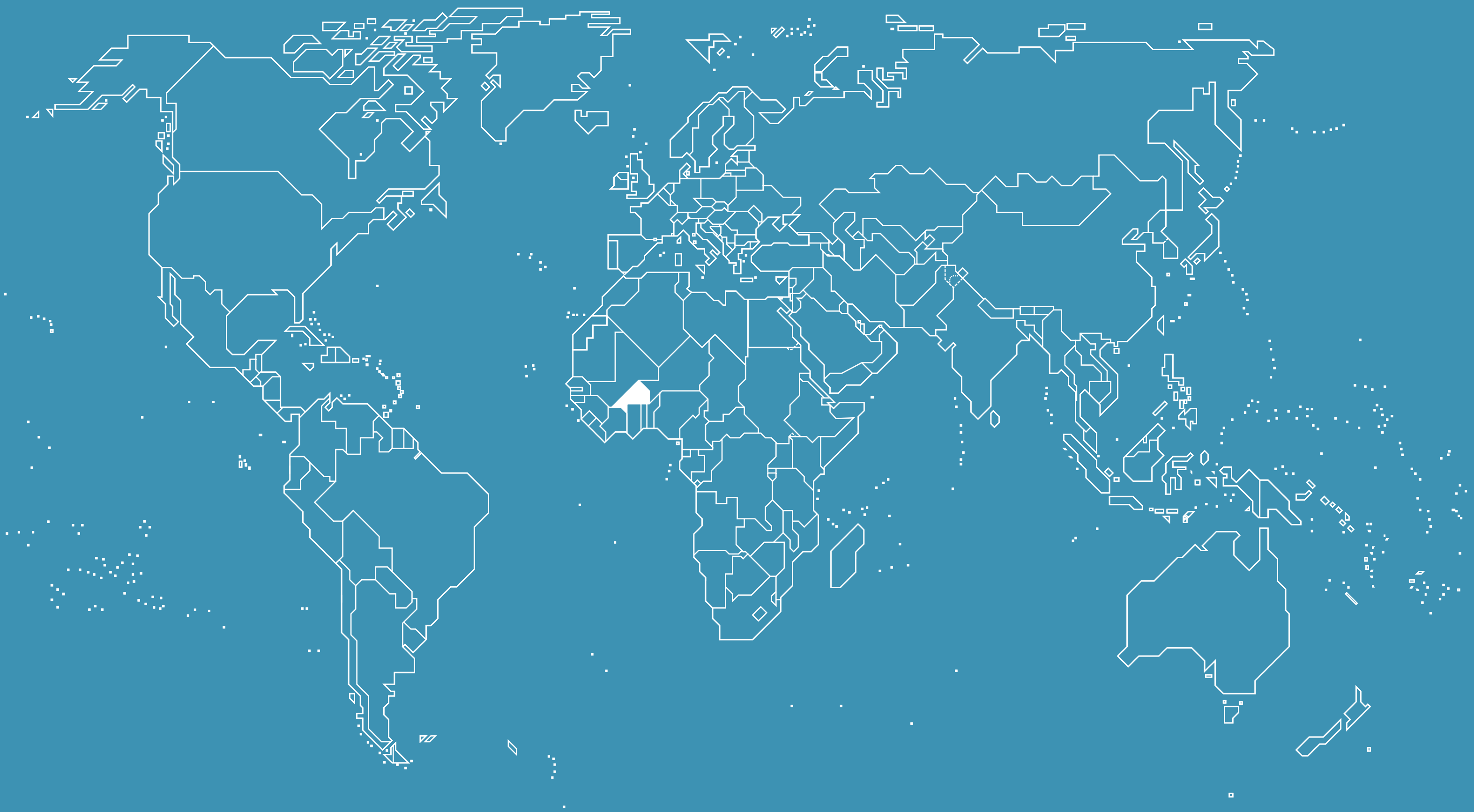


Burkina Faso

Author: Zounoubaté N'Zombié

Burkina Faso

BACKGROUND

At the conference on Biosolids organised by the International Water Association (IWA) in Moncton (Canada) in June 2007, representatives of IWA, WEF, and EWA agreed that it would be useful to produce a second edition of the atlas published in 1996 and edited the first time by IWA. It was retained that the same format will be used but will be modified/amended to include experiences of the past ten years and modern needs and interests, including the treatment of faecal substances.

The current document provides the contribution of the « Water for African Cities, Phase II » programme team in Burkina Faso.

Located at the heart of West Africa, Burkina Faso covers an area of 274 200 sq km and hosts about 13.7 million inhabitants (RGPH, 2006). According to World Reports on Sustainable Human Development of UNDP, the Human Development Indicator (HDI) of the country has been the lowest in the world in the past decade. The Human Development Index (HDI) in 2007 was 0.37 thus placing the country at the 176th position out of 177 countries. We are therefore faced with one of the most vulnerable populations in the world, whose capacity to react to economic and temporal crises is very weak. The population is young and mostly illiterate: the average age is around 23 years, the gross combined literacy rate stands around 26 % and illiteracy affects about 79% of the population.

Despite a real growth rate in the GDP which is estimated at 5.5% on the average for the period between 1995 and 2002, about 46.4 % of the population lives below the absolute poverty line (EBCVM of 2003) against 45.3 % in 1998. Poverty affects more women (52 %) than men. Twenty-three percent of the rural population live in utmost poverty/misery.

In the rural areas, the issue of excreta management is addressed by autonomous sanitation facilities based on in situ treatment. The main technical precautions taken to facilitate the implementation of these solutions are linked to the following:

- Ability of the underground to stock these excreta: optimal permeability and minimal hydromorphical conditions (absence of seasonal variations of the ground water at shallow/superficial layer),
- Minimal volume of excreta storage to reduce/limit inconvenience and health problems related to periodic emptying of tanks/pits,
- As much as possible, the doubling of pits to allow the stabilisation of mud for one or two years to eliminate most pathogenic agents, outside cysts.

There are several technologies likely to help contribute to the attainment of MDGs and yet, only a few of them are currently available in Burkina Faso.

However, beyond excreta management, the management of grey/used waters (waters from general washing, dishwashing and clothes washing and bathing) in rural areas is not checked and in some cases, specific construction efforts are required.

It is unfortunate to note that more than 80% of the population use the environment to evacuate excreta, and almost all of these people also throw their domestic/household wastewaters into the environment.

In urban areas, the question of sanitation is being addressed by an innovative and original approach through the elaboration and application of Strategic Sanitation Plans (SSPs). The plan for Ouagadougou, which started in the 1990s, is based on two pillars:

- A political will explicitly expressed in the January 1996 paper on 'National strategy on the subsector of sanitation in Burkina Faso' and approved by the council of ministers;
- An operational strategy conducted by the National Water and Sanitation Board (ONEA).

Six cities in all have their own strategic sanitation plans but the lack of financial resources has hindered the access rate to sanitation facilities, which remains poor for urban centres managed by ONEA.

It is against this background that the Government of Burkina Faso adopted in December 2006, a Water and Sanitation supply (WATSAN) Programme by 2015, instrument by which Burkina Faso, in accordance with its Strategic Framework for Poverty Reduction aims at achieving the Millennium Development Goals (MDGs) in the WATSAN sector.

HOW ARE THESE SUBSTANCES MANAGED?

In Burkina Faso, measures have been taken to evacuate household wastewaters and excreta (faecal substances) through diverse types of latrines (traditional and improved), pits and sewage networks, even if access rate to these facilities are still poor/weak.

Access rate to sanitation facilities at the end of 2007 was estimated at 15.6% on the whole Burkinabe territory. This poor access rate to wastewaters and excreta sanitation facilities is due to the complex nature of access to sanitation in rural areas where it is estimated at 10%, considering that part of the existing traditional latrines, visited by about 20% of households, respects security, efficient use and sustainability requirements.

In urban areas, ONEA has only intervened in two big cities, where SSPs have been implemented and the access rate to sanitation hit 55.82% in Ouagadougou and 31.68% in Bobo Dioulasso.

Furthermore, there is in Ouagadougou, a wastewater treatment plant, where industrialists have the possibility to connect after a pre-treatment of their wastewaters. BRAKINA and the slaughterhouse are connected to the collective network.

Apart from the centre of the city of Ouagadougou and factories located on the axis going from the purification plant, other industrial wastewaters are not always treated before they are thrown into the environment. The other uncontrolled substances remain used oils/lubricants and expired or old phytosanitary/plant-care products.

Farmers request that sewage products be emptied into their farms to increase their agricultural yields.

STRATEGIC CHOICES

Management of wastewaters and excreta

Under the WATSAN national programme, three components were identified for the management of wastewaters and excreta, namely:

- Autonomous sanitation proposed for the management of wastewaters and excreta in most households where evacuation and treatment are done on the ground with the surroundings through simple but effective technologies and adapted to the ability of the inhabitant to pay for the services rendered.

  Consequently, according to the technical feasibility, the cost and preference of users, autonomous sanitation was proposed for households in the form of latrines with ventilated pits, latrines with manual flush, cesspools, septic tanks or rehabilitation of existing traditional latrines for the evacuation/draining of wastewaters and excreta;
- School and community sanitation through the equipping of schools and public places with autonomous sanitation facilities ;
- Collective sanitation through the creation of sewage networks to collect and transfer wastewaters of big polluters (factories, hotels, hospitals, big markets) into the purification/treatment plants, where they will be treated by lagooning to meet the norms/regulations in force before they are reused under securing hygienic conditions (agriculture, brick works, etc.).

In the case of improved latrines such as VIP or Ecosan, faeces and urines are « hygienised » and reused for market gardening.

Earth bank or incineration

They are neither mounded nor incinerated.

Use of lagoons?

Apart from controlled wastewaters, most of wastewaters and excreta are thrown into the environment. The picture here shows a lagoon where the industrial wastewaters of the sugar factory in the area of Banfora were thrown.

Description of methods of compost

Handmade compost used in smoking pits is the most practised method to achieve objectives of agricultural production set each year between political authorities and producers.

Industrial compost is done on waste treatment and recycling sites in Ouagadougou.

DECISION-MAKING

How are decisions taken?

Decisions are taken based on the interests of the following actors (promoters):

- households;
- municipalities;
- government.

Households

In order to improve the living conditions and standards and to preserve the health of the family, households decide either to build a latrine (traditional or improved), install a septic tank or to get connected to the collective network if the housing is of a certain standard; this decision is guided by capacity to pay for and manage the facility and space availability.

Municipalities

In accordance with the general code of local government, local collectives contribute with the State to the management and arrangement of the territory, to the economic, social, educational, health, cultural and scientific development as well as the protection, valorisation of natural resources and to the improvement of living standards (article 32). In the national sanitation policy and strategy document, municipalities are authors of sanitation activities in their part of the territory. As such, the municipality, under its communal development programme, plans sanitation activities to be conducted and searches for necessary funding.

Government

Ministerial departments involved in the implementation of national sanitation policy and strategy include the following:

- Ministry of Environment, in charge of the coordination of sector-based sanitation policy and strategy. The ministry of Environment is also in charge of the subsectors of solid wastes, wastewaters, gaseous wastes in consultation with Ministries in charge of Health, Water, Habitat, Urbanism, Education and Research.

- Ministry in charge of Water, for the component « wastewaters and excreta » of subsectors of wastewaters and solid wastes in consultation with Ministries of Health, Habitat, Urbanism, Education and Environment.
- Ministries in charge of Infrastructures, Habitat and Urbanism for the subsector « rain waters » in coordination with Ministries of Environment and Water

However the Ministry of Finance participates in decision making as it is the authority responsible for allocating financial resources to other ministerial departments and also negotiates and signs funding conventions with development partners.

Evaluation of risks

Under the construction works programme designed by an institution, environmental impact assessments are conducted and mitigation or improvement measures are taken and implemented under the supervision of the Ministry of Environment.

Process of decisions-making

The choice of the type of treatment depends on the promoter and it is generally based on the cost, so it depends on the income of the household. For other stakeholders, decisions are mainly political (defined national priority), then they depend on technical feasibility, economic and financial feasibility and finally on availability of financial resources.

Who takes the decisions?

At households' level, decisions are taken by heads of households.

The municipal council chaired by the Mayor takes the decisions and they are executed by the Mayor.

Ministers involved in the implementation of sanitation activities in a framework of consultation.

ECONOMY

Table 1. Cost of wastewaters and excreta management works

No	Designation	Cost of equipment (CFA Francs)	Sewage or treatment charges/year (CFA F)
1	Ordinary Latrines (traditional)	12 000 to15 000	1 000
2	Watertight pits	60 000 to100 000	30 000
3	VIP Latrines with 1 or 2 pits	60 000 to 250 000	5 000*
4	VIP latrines blocks (6 or 7 posts)	1 750 000 to 2 500 000	10 000*
5	Toilet with manual flush	130 000 to 150 000	30 000
6	San plant Latrine	30 000 to 70 000	-
7	Ecosan Latrine	80 000 to 100 000	-
8	Septic tank	250 000	30 000
9	Cess pool	10 000	-
10	Infiltration pits or dead well	40 000	-
11	Collective sanitation network of Ouagadougou (40 km)	3 500 000 000	35 F/m^3

(*) Every 2 to 3 years

Charges paid by customers

Currently the customers of ONEA pay 21 CFA F per cubic meter of wastewater.

Cost of fuel (diesel)

The cost of 1000 litres of diesel fuel varies between 603 000 CFA F in Ouagadougou and 620 000 CFA F in Dori. We must note that the price fluctuates according to prices of a barrel on the international market.

Cost of electricity

The cost of electricity per kilowatt/hour varies between 96 CFA F and 109 CFA F.

PROCESS OF TREATMENT, USE AND/OR DISPOSAL

Excreta management

Concerning autonomous sanitation, there are several types of works that are usually used and they are mostly in situ treatment: traditional latrines, watertight pits, VIP latrines with one or two pits, San flat latrines, toilets with hand flush, ECOSAN latrine, and septic tanks. Only improved forms of these facilities are promoted in the implementation of programmes financed by official Development Assistance.

Sewage management

The most common sewage method is the manual sewage inside or in the proximity of households. Mechanical collection with spiros trucks is only available in cities such as Ouagadougou, Bobo-Dioulasso, Banfora, Ouahigouya and Pouytenga.

Collected wastes are most often thrown into the environment in the surroundings of communities or farms at the request of exploiters. A recent study on the city of Ouagadougou revealed that 58% of households having latrines call upon sewage trucks whereas 41% depend on manual sewage collectors. The study estimates the production of sewage wastes at 400cubic meters a day.

The current state of available information shows that the process is not at all controlled on the whole of the territory.

For the city of Ouagadougou, exchanges were undertaken in 2006 and dumping sites were identified with the common agreement of the Ministry of Environment, Ministry of Health, ONEA, the municipality of Ouagadougou and CREPA. Three zones were identified and four sites were reserved.

Wastewaters management

Apart from cesspools and infiltration pits or dead wells, the following systems also exist:

Low-diameter sewage network

A low-diameter sewage network is made up of intermediary pits (interception pits) which hold substances in suspension placed inside houses. These pits are connected to a network of low-diameter pipelines (100 mm to 250 mm) which drain sedimented waters towards an existing classical sewage network or a treatment plant.

This is a relatively new technology, not yet sufficiently mastered in the national context. An applied research programme is ongoing in Ouagadougou under the auspices of CREPA and EIER. It consists of the realisation of a mini-network for the collection of wastewaters in EIER villas and in their treatment in CREPA's Headquarters plant. Two other networks are under construction respectively in Somgandé, an area of Ouagadougou under the « Water for African Cities, phase II » programme and in the city of Bobo under the funding of CREPA.

Classical sewage network

This is a collection system of wastewater remnants in pipelines of minimal diameter of 250 mm, ending at the treatment plant. It allows the drainage of important quantities of wastewaters but requires qualified labour and regular maintenance with very costly mechanical means. The city of Ouagadougou was granted, under the Strategic SANITATION Plan, a 40 000 ml pipeline. A network of 14 000 ml is under construction in Bobo-Dioulasso. Respective costs of these infrastructures amounts to 3.1 billion CFA F for Ouagadougou and 2.5 billion CFA F for Bobo-Dioulasso.

The design of these networks requires several parameters which need to be adapted to local constraints (point coefficient, minimal draught gauge, minimal slope, auto clearing-out, solid wastes transportation, minimal maintenance frequency, etc.). It is indispensable that such studies be conducted in Burkina Faso for a better operation of these types of installations/facilities.

Wastewaters treatment plant

Lagooning is one of the alternative technologies for wastewater treatment that simulates the purifying effect of natural aquatic environment but also amplifies them. It is a process that uses the combined effect of micro-organisms, algae and ultraviolet rays to stabilise the organic substances in mineral substances and then eliminate even bacteria through auto oxidation and destruction of their cells by the same UV rays.

Built on an area of 13 hectares against the expected 20 ha, with a volume of 180 000 cubic meters, the treatment plant of Kossodo in Ouagadougou is made up of: (i) 8 lagooning basins (1st floor: 3 parallel anaerobic basins; 2nd floor: 2 optional basins built in parallel and the 3rd floor: 3 mass maturation basins; (ii) 28 beds of 95 square meters each, totalling 2660 sq meters, (iii) 1 laboratory and 2 administrative buildings as well as latrines.

Dimension parameters of the basins are:

- 5400 cubic meters a day (m^3/day) (phase I) and 11600 cubic meters a day (m^3/day) (phase II) ;
- equivalent /inhabitants ;
- Time of retention of pollutant charges: 30 days ;
- Coliform faeces: 1000/100ml.
- Surfacic charges lower than 100-140kg/ha/day at the end of the basins

The production/yield of the treatment plant is greater than 90 %.

Use of treated water

Treated wastewaters are used for market gardening and flower growing according to the standards of reuse set by WHO. Indeed upstream from the Kossodo treatment plant, market gardeners who were settled on a perimeter of 11.3 hectares have recently moved to occupy the other 30ha available. Regular monitoring is conducted to ensure the management of susceptible risks linked to the use of treated wastewaters. A plan of communication and management of risks has been put in place for this effect. The modes of application of treated wastewaters on different types of crops as well as measures of protection for the users were adopted and defined in the plan.

Contamination

To avoid any contamination, wastes emptied into lagoon basins are further treated on drying beds and used for compost or sent to be buried at the wastes treatment and recycling centre.

LEGISLATIVE AND REGULATORY FRAMEWORK

Laws and/or regulations/rules

The Government of Burkina Faso has adopted laws, decrees and legislation that regulate the sanitation sector. Some of these decrees and legislation are being reformed or elaborated so they will conform to current institutional development experiences by the sanitation sector.

Elimination of excreta

- Law n°014/96/ADP of the 23rd May 1996 on Land and Property Reorganisation (article 117)
- Law n°23/94/ADP of 19th May 1994 on the Code of Public Health (Article 53);
- Law n°022-2005/AN of 24th May 2005 on the Code of Public Hygiene (Article 30)
- Law n° 005/97/ADP of 30th January 1997 on the Code of the Environment (article 2)
- Law n°055 -2004/AN of 21st December 2004 on the general Code of Territorial Administration (article 89)
- National Sanitation Policy and Strategy (July 2007)
- National Policy on the Environment (decree n°2007-460/PRES/PM/MECV of 30^{th} March 2007)
- Strategic Sanitation Plan (SSP) of Ouagadougou (1993).

Controlled collection, treatment and elimination of sewage wastes

- Law n°014/96/ADP of 23rd May 1996 on Land and Property Reorganisation (article 117)
- Law n° 005/97/ADP of 30th January 1997 on the Code of Environment of Burkina Faso (article 5)
- Law n°055 -2004/AN of 21st December 2004 on the general Code of territorial administration (article 89)
- National Sanitation Policy and Strategy (July 2007)
- Strategic Sanitation Plan (SSP) of Ouagadougou (1993).
- National Policy on the Environment (decree n°2007-460/PRES/PM/MECV of 30^{th} March 2007)
- Policy and Strategy on Water (1998)

Wastewaters treatment

- Law n°23/94/ADP of 19th May 1994 on the Code of Public Health (Article 53) ;
- Law n°022-2005/AN of 24th May 2005 on the Code of Public Hygiene (Article 30)

- Law n°002-2001/AN of 8/2/2001 on the orientation Law for water management (article 6)
- Law n° 005/97/ADP of 30th January 1997 on the Code of Environment of Burkina Faso (article 5)
- Law n°014/96/ADP of the 23rd May 1996 on Land and Property Reorganisation (article 117)
- National Sanitation Policy and Strategy (July 2007)
- National Policy on the Environment (decree n°2007-460/PRES/PM/MECV of 30th March 2007)
- Decree n° 98-322/PRES/PM/MEE/MCIA/MEM/MS/MATS/METSS/MEF. The present decree determines conditions for the set-up and operation of dangerous, unhealthy and inconvenient establishments.
- Strategic Sanitation Plan (SSP) of Ouagadougou (1993).
- Decree n° 2001-185/PRES/PM/MEE, of 21st May 2001, on the discharge of pollutants in the air, water and on the ground

Reuse

- *Human Excreta*
  WHO guidelines on the reuse of excreta and washing waters for agriculture (Vol. IV, 3rd edition, 2006)
- *Sewage wastes*
  WHO guidelines on the reuse of excreta and washing waters for agriculture (Vol. IV, 3rd edition, 2006)
- *Municipal wastewaters*
  Decree n° 2001-185/PRES/PM/MEE, of 21st May 2001, on the discharge of pollutants in the air, water and on the ground
  WHO guidelines on the reuse of wastewaters in agriculture (Vol. II, 3rd edition, 2006)

National Sanitation Policy and Strategy (NSPS)

The global objective of the NSPS is to contribute to sustainable development by bringing appropriate solutions to sanitation-related problems so as to improve the living and settlement conditions of populations, to preserve their health, and to protect natural resources. The policy is based on five (5) principles including the principle of subsidiarity: "For more efficiency and accountability in the implementation of actions, the principle of subsidiarity allows actors to take decisions according to their capacities at the most appropriate level."

The strategy for the implementation of the National Sanitation policy will develop the following key ideas:

- Make municipalities the privileged actors of communication and dialogue for the promotion of sanitation, for the expression of their needs, the planning and implementation of solutions adapted to the local context;
- Deploy all institutional and regulatory measures to involve sanitation actors in the elaboration and implementation of sub-sectorial action plans ;
- Ensure the sustainability of actions to be undertaken, namely through national and local capacity building in sanitation.

Eleven (11) axes of intervention have been identified aiming, among other things, at:

- Subsidising sanitation activities
- Defining clearly the missions of the different actors (government, central/decentralised administration, local government, private sector, households, etc.)
- Promoting the training and education of populations on hygiene and sanitation-related issues
- Basing the choice of standards on the effective demand of users
- Involving communities as early as during the conception and formulation of programmes and considering them as full-time representatives of all the stages of the programme
- Developing an information, communication and dialogue system adapted to the various categories of target public
- Formalising relationships with the populations through their organisations
- Building negotiation capacities of all the different stakeholders

Risks evaluation

The evaluation of risks supports these Laws. Indeed, the environmental impact assessment or notice is based on the Code of the Environment. One of its application decrees is decree n°2001-342/PRES/PM/MEE of 17th July 2001 on the application field, content and procedure of the environmental impact assessment and notice. The impact mitigation and improvement measures generally defined in the environmental and social management plan are always based on Laws and regulations in force (Laws, policies and strategies and application decrees).

STABILISATION AND/OR DISINFECTION TECHNIQUES

The treatment methods used for wastewaters are:

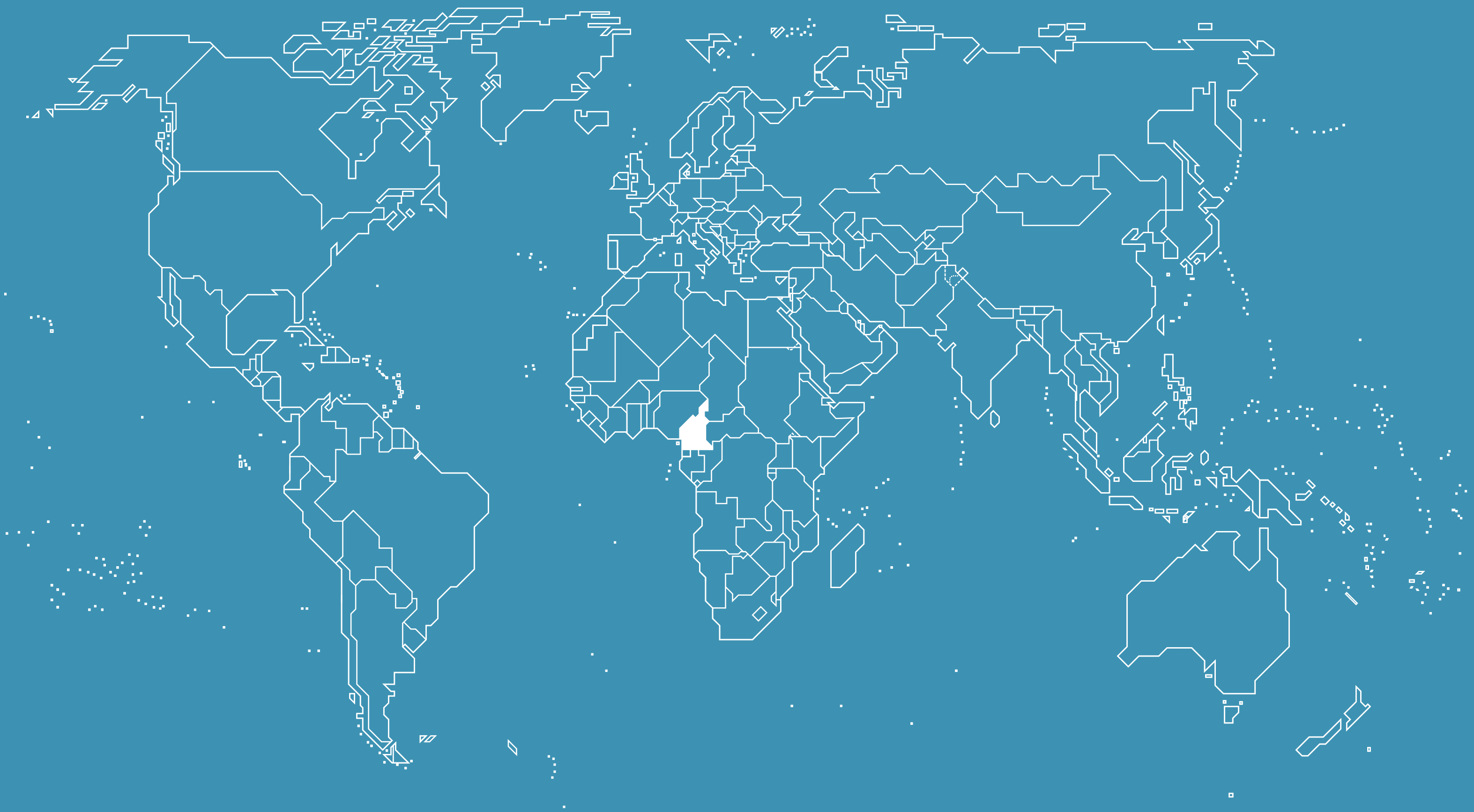
- Lagooning operating in aerobics and anaerobic,
- Cesspools
- Septic tanks

HOT QUESTIONS/ISSUES

The review of the following legislations is envisaged:

- Law n°014/96/ADP of the 23rd May 1996 on Land and Property Reorganisation (article 117)
- Policy and Strategy on Water (1998)
- Decree n° 2001-185/PRES/PM/MEE, of 21st May 2001, on the discharge of pollutants in the air, water and on the ground

To this legislation, regulations on the management of sewage wastes are added but no schedule has been defined.



Cameroon

Author: Parfait Roger Nkoulou Mfoulu

Cameroon

CONTEXT

IWA, WEF, and EWA representatives agreed in June 2007 at the IWA Biosolids Conference in Moncton, Canada, that it would be useful to produce a second edition of the Atlas produced in 1996 and published by IWA. It was agreed that the same format should be used, but modified to reflect experiences of the past ten years and contemporary needs and interests, including the addition of the disposal of fecal matter.

Cameroon's Water for African Cities team, with UN-HABITAT support, offers its contribution for the Atlas in this short document.

Cameroon is a Central African country with an area of 475.445 sq km and estimated population of about 15 million inhabitants. It possesses several water streams, most of which trace their source to the Adamaoua Plateau?.

Urban population growth has been very high and potable water supply and sanitation problems have begun to threaten the aquatic ecosystems. Because of this deficit between the supply and demand of potable water, and problems caused by uncontrolled development of human settlements and industrial waste, Cameroon is facing a very worrisome water resources situation.

Sector-based strategies and policies in the water sector have been reviewed and reinforced in recent years. They conform to the international community's general water direction and policies while respecting local particularities.

The unfavourable geo-ecological situation on one hand and the lack of appropriate policies on the other have hindered the search for long-term solutions. The management of faecal waste in particular is not efficient and threatens the environment.

Although there are ways of managing faecal matter, it is dumped into the environment. Moreover, more than 60% of household solid wastes are biodegradable.

This situation is rooted in the traditional ways of managing faeces:

Cameroonian houses were traditionally equipped with a 2-meter-deep hole, surrounded by pieces of timber. When the hole was full, it was covered by ground and medicinal or aromatic plants, and another facility was built. When in the bush, people relieved themselves on the spot.

Villagers continue to use this practice because they have no choice. However, as villages grow, such facilities as wells and boreholes are now too near houses, threatening and water quality. Land issues prevent digging new holes, so full latrines pose a major problem.

This traditional method is also used in poor urban areas. Land pressure is higher and faeces are removed by tank trucks, but they are unfortunately dumped into rivers or the forest, because there are no treatment facilities.

Houses in modern residential areas have septic tanks, and treated used water is directed into a well for filtration, but this often does not happen because builders do not master the technology.

Sewerage systems are built in collective residential areas, universities and hospitals, and houses are connected. Effluents are directed into a treatment plant, and treated water goes into a river.

Aside from these measures, municipalities and the central government do not have the money to build collective facilities. So, near market places and wild car station, there are also wild places without facilities.

It is obvious that giving value to excreta can change the environment of cities and villages. Evaluating the possibilities of valorisation for biosolids could save some people from poverty. Actually, available data are those from the capital Yaoundé. A master plan has been studied by a French consulting firm with the financial support of the African Development Bank.

OVERVIEW OF HOME SANITATION: CLASSIFICATION EFFORTS

Data from sanitation master plan shows the following results:
There are three categories of individual sanitation:

- The first is those using flush toilets. Three types exist::
  - Indoor toilets: the water-consumption rate is 75 l/day/person; and some of them are linked to a sewerage system.
  - Outside toilets: the water-consumption rate is 50 l/day/person
  - Common toilets: the water-consumption rate is 25 l/day/person
- Those using latrines use two types:
  - Private: the water-consumption rate is 20 l/day/person
  - Common latrines: the water-consumption rate is 20 l/day/person
- Other categories

SLUDGE AND FAECAL SLUDGE MANAGEMENT

The last published census of population and housing (1987) and current estimates give the following results, assuming that population of Yaoundé is 2,000,000 persons:

Table 1. Yaoundé data

	Flush toilets			Latrines		
	Indoor 75l/day/ person	External 50 l/ day/ person	Common 25 l /day/ person	Private 20 l/ day/ person	Common 20 l/ day/ person	Others
Percentage of people concerned	18.4%	3.2 %	4.3 %	24.9 %	47.3 %	1,9%
Estimated people concerned 2007	368,000	64,000	86,000	498,000	946,000	38,000
Used water produced m^3/ day	27,600	3,200	2,150	9,960	18,920	760
Sludge production In m^3/year	29,366	5,107	6,863	39,740	75,491	3,032

This table gives a total of 159,600 m^3/year sludge production in Yaoundé. By extrapolation, there is a strong probability that urban areas in Cameroon (about 9,750, 000 persons) produce about 778,000 m^3 of sludge a year.

Quantity managed in Cameroon urban areas annually

Table 2. Yaoundé

	Managed	Population concerned	Ignored	Observations
Grand Messa treatment plant	450 m^3 per day 4,500 hab eq 243 kg BOD5 a day	10,000	All, as the plant is stopped; about 20,000 people are ignored	Mingoa watershed Activated sludge mean charge
Cité Verte treatment plant	1,030 m^3 per day 12.000 hab eq 570 kg BOD5 a day	25,000	Stopped since 1989, all effluents are bypassed to the river	Abiergué watershed Activated sludge low charge
University campus Ngoa Ekelle treatment plant	500 m^3 per day ****** 195 kg BOD5 a day	25,000 students	Running but in bad repair	Olezoa watershed Activated sludge low charge
Medical faculty treatment plant	425 m^3 a day ****** 141 kg BOD5 a day		Does not work	Olezoa watershed Activated sludge
Nsam treatment plant project (estimates)	5,943 m^3 a day 29,014 eq hab 2,031 kg a day	29,014	Stopped and in a bad state of repair	Mfoundi watershed Activate sludge (low charge) Construction stopped since 1987
Unity Palace (state house) Treatment plant	190 m^3 a day 2,150 eq hab 69 kg BOD5 a day		Stopped, effluents are bypassed	Mfoundi watershed Activated sludge low charge

	Managed	Population concerned	Ignored	Observations
General Hospital treatment plant	355 m³ a day 855 eq hab 46 kg BOD5 a day		Running	Ntem watershed Activated sludge low charge
Biyem Assi residential area treatment plant	Unknown data	25,000	Running but problems with the disposal of removed aquatic plants	Biyeme watershed Lagoon and aquatic plants
Technical secondary school Nkolbisson treatment plant	144 m³ a day 29 kg BOD5 a day		Running well	Mfou watershed activated sludge low charge
Social insurance fund Essos hospital treatment plant	120 m³ a day 15 kg BOD5 a day		Running well	Ebogo watershed Activated sludge
Septic tanks	0	308,000	All is ignored, that is an estimated potential of 24,600 m³ per year of sludge to be removed by truck tanker and dumped into the river or forest	There is no treatment plant dedicated to removed sludge
Traditional	0	1,444,000	All is ignored, that is an estimated potential of 115,000 m³ per year of sludge to be removed by truck tanker and dumped into the river or forest	There is no treatment plant dedicated to removed sludge

Yaoundé's situation is the best in the country; it is worse in other cities. That means there is probably a level of 682,500 m³ of unmanaged urban sludge a year; if it is optimistically assumed that all treatment plants run properly; which is not the case. Unmanaged sludge means pollution.

Strategic selection of disposal practices

No statistics are available; this data is based on estimates. It is important to note that liquid wastes go to rivers and sludge goes into the bush, as there is no treatment plant for sludge removed from septic tanks or latrines or for sludge from treatment plants.

Landfill is not commonly known as a technique for dealing with to sludge.

Table 3. Disposal estimates

	Disposed of into water resources		Disposed of into the bush		Disposed of into lagoons		Disposed of as landfill	
	Effluent	Sludge	Effluent	Sludge	Effluent	Sludge	Effluent	Sludge
Sewage	90%	Not managed	0%	90%	10%	10%	0%	0%
Septic tanks	Underground	90%	0%	10%	0%	0%	0%	0%
Traditional	Underground	100%	0%	0%	0%	0%	0%	0%

DECISION MAKING

Considering that partners involved in the management of excreta are:

- Families
- Municipalities
- The government through:
  - The Ministry of Energy and Water Resources
  - The Ministry of Environment and Protection of Nature
  - The Ministry of Urban Development and Housing

The decisions are taken with substantial involvement of each of these entities.

How decisions are made

By families:

Families aim to at least have safe houses and, if possible, comfortable ones. Given the previously cited land pressure and the absence of treatment plants for sludge management, excreta management is a major challenge.

- Where there is sewerage, decisions are made by housing companies. Experience shows that this method does not work properly. Families are not satisfied by what is done.
- Where septic tanks are used, when tanks are full, families call private companies to empty the tanks with tankers (trucks with a steel tank and a sludge pump)
- Where traditional latrines are used, when the tank is full, families take one of two courses of action:
  - When the family has no land to dig another hole (it is most often the case), and if the family has U.S.$120, they can call the tanker. Sometimes, while saving up the $120, excreta overflows.
  - When the family has a lot of land, the hole is filled in, and spice plants grow on the top of the former hole.

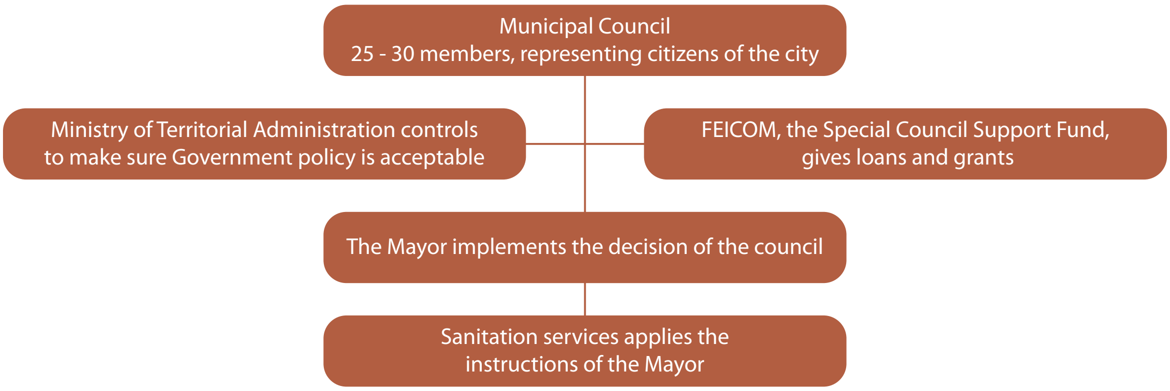
One consequence of the traditional latrine is that in the poor urban areas, to avoid paying for the truck, the hole is dug very deep; threatening underground waters. In addition, land pressure is so high that very often trucks cannot get to slum houses.

Last but not least, regulations and laws are rarely applied, so family decisions are driven by other interests. It has happened that a family emptied its latrines and poured the sludge into the street gutters nightly…

By municipalities:

Municipalities dream of clean cities, but lack of money means that they must set priorities, and sanitation is not a very high priority. Solid wastes are removed, but liquid wastes are ignored and families are often left on their own.

The decisions flow down as shown in this chart:



The decisions are driven by technical, financial and political feasibility.

By Government:

Three government bodies are involved in the management of excreta. The Ministry of Energy and Water Resources is in charge of the management of water resources, the Ministry of Environment is responsible for protection of nature and the Ministry of Urban Development and Housing handles housing and urban policy.

The fact is, however, that those bodies are not really coordinated well. The lack of budget means decisions are driven by political concerns; it is more attractive for a politician to provide water than remove waste water.

Involvement of risk assessment

In theory and according to legislation, of course, risk assessment must be part of sludge and excreta management.

In practice, this is not the case and things are done without evaluation of risk.

Factors driving decisions

Decisions are driven by the particular interests of the bodies involved:

- Politicians consider politics
- Families consider their well being and priorities

Who makes decisions?

- Family chiefs for families
- Municipal councils for municipalities
- Three ministries for the Government

ECONOMICS

Table 4. Disposal costs

	Cost of disposal		Cost of treatment		Cost of 1,000 Liters of Diesel fuel		Cost of 1kWh of electricity	
	Yaoundé and Douala	**Other areas**	**Yaoundé and Douala**	**Other areas**	**Yaoundé and Douala**	**Other areas**	**Yaoundé and Douala**	**Other areas**
Sewerage	Included in the rental price	Does not exist	Included in the rental price	Does not exist	More than U.S.$1,120	More than U.S.$1,200	U.S.$0.12	More than U.S.$0.12
Septic tanks	U.S.$120 per full tank truck	More than U.S.$120 per tank truck	Nothing	Nothing				
Traditional	U.S.$120 per full tank truck	More than U.S.$120 per tank truck						

Conclusions on costs

The required cost is what is needed to empty sludge from plants, septic tanks or latrines. Frequently, it consists of the tanker fees.

For sewerage, electricity needed for the treatment plant is a collective fee included in rent. However, experience shows that management is inefficient: there is no well-managed treatment plant in Yaoundé, so there is a need for bettermanagement tools.

In all cases, the costs are too high for most people involved.

TREATMENT, USE, AND/OR DISPOSAL PROCESSES

Processes used depend on the type of facility, and this depends on the living standard.

For sewerage, the reader can consult the table above on Yaoundé treatment plants. The situation in Douala is the same.

For the traditional method, a description is also included in the Context section above: there is no treatment, but reuse as fertilizer after the hole is full.

Some other practices exist as outlined in Table 5.

Use and disposal processes

Except for the case of traditional latrines, excreta are considered as true waste. No treatment plants exist to manage sludge removed from full latrines, septic tanks or treatment plants.

Table 5. Processes of treatment

Technology	Process	Calculation of size	Avantages	Observations
Odorless REED latrine and/or ventilated latrine	Hole with an aeration pipe on the back to ameliorate the wind effect. – Entrance oriented in front of wind direction – the wind blows air into the pipe, creating a flow of air passing from: door to defecation hole to pipe, so there is no odor inside the latrine – The superior face of the pipe holds a grid that traps insects, preventing flies from entering the pipe and then leaving and spreading contamination	where **Ams** : ratio of accumulation of solid matters, normally 0,06 m^3/user/year **n** : number of users per latrine **d** : time to be full more than one year V in m^3	Suited to water-shortage conditions Can be transformed into U bend latrines	*Conditions of use*: Permeability more than 2,5 mm/h Water table more than 1m deep If the water table is higher, the latrine is raised
U-bend Latrine	Two parts : 1 flagstone with a U-bend vase incorporated for the hydraulic closing. 1 or 2 draining pit After defecation, one to two litres of water are poured in the U-Bend. The hydraulic closing eliminates odors and isolates the excreta. Faecal matters biodegrade in anaerobic and aerobic conditions – Residues infiltrate in the ground	where **Ams** : ratio of accumulation of solid matters, normally 0,06 m^3/user/year **n** : number of users per latrine **d** : time to be full more than one year V in m^3	Possibilities of being transformed in latrines linked to a small diameter collector pipe When a water supply network is available, it can be transformed easily into a modern flush toilet	*Conditions of use*: Permeability more than 2,5 mm/h Water table more than 1m deep If the water table is higher, the latrine is raised At least one outdoor water tap (5l/user/day)
Low diameter collector	Designed to receive the liquid part of domestic effluent Fats and settlement matters separated in a tank (septic or draining)	Hydraulic laws. No need of particular slope or spped for **s**elf scouring Criteria: Alignment of slopes; slope variation allowed; increasing slope sometimes allowed; Trap visits are rarely necessary; cleaning traps 200 or 400 mm diameter enough Mean rate of flow enough for calculation (instead of peak rate of flow)	Low consumption of water Reduced banking works cost Reduced materials costs Reduced treatment needs Intermediate step to full sanitation	Actually implemented by ENDA rup under WAC 2 for UNHABITAT in Douala and Edéa
Septic tank	2 processes : decantation to separate particles of density different from the water's Fermentation of settled sludge according to processes leading to partial liquefaction of degradable organic componants, to decrease quantity of sludge and organic matter.	Number of users / Tank Volume in m^3 / Retention time in days: 5 / 2,5 / 5,2 10 / 3,5 / 3,6 15 / 4,5 / 3,1 20 / 6 / 3,1 25 / 7,5 / 3,1 50 / 12 / 2,5 100 / 20 / 2,1 150 / 40 / 2,1 (Pour the 2 tanks) Good for high standard-of-life areas 120l/day/hab, 80% of rejectionsoit 96l/j/hab. Source : plan directeur d'assainissement de la ville de Yaoundé – par SOGREAH ingénierie – Normes et critères du projet – Décembre 1992 Useful water level more than 1m + 25cm high for retention of floating matters.	30 to 50% of pull down of BOD and pull down of suspended solids between 50 and 70% Reduction of 10% of total nitrogen Reduction between 20 and 30 % of phosphates	

LAWS AND REGULATIONS

Water regime law

Disinfection and stabilization techniques

No treatment available except in the existing treatment plant where disinfection is not practiced

HOT ISSUES

There is no treatment plant for the sludge removed from full tanks and latrines.

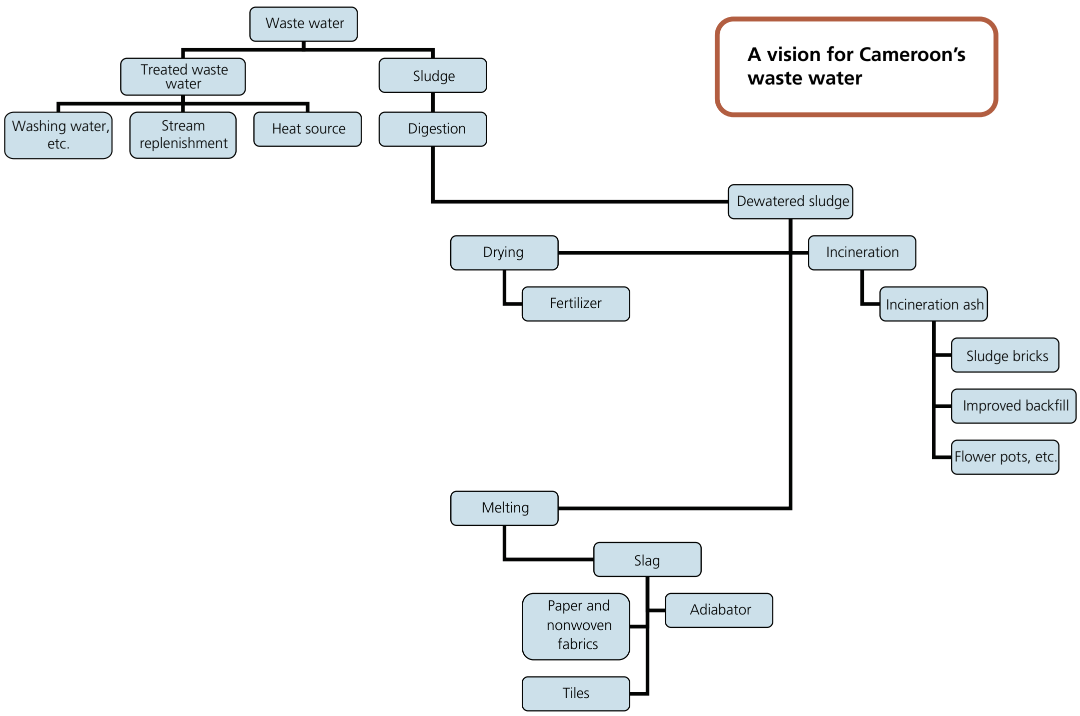
There is an ecological disaster in progress in the open in Yaoundé, in the village of Nomayos 1, where effluents are all disposed of into the environment. Each day, 10 trucks of 6,000 liters each come near the village throw sludge into the Avo'o River. This village has an estimated population of 500. Potable water is produced downstream.

Sludge management in Cameroon is a very serious situation, but using best sludge management could produce a very happy ending. It is known from the experience of countries like Japan and others, that sludge management helps a nation:

Witnesses say the color of water in the river has changed and fish no longer live in the river. Villages living on domestic economies rely on nature for most of their resources.

It is reported that some villagers take a tax of $2 per truck and rural mayors (outside of Yaoundé) take $6 a truck.

Some dangerous illnesses are appearing.



A vision for Cameroon's waste water

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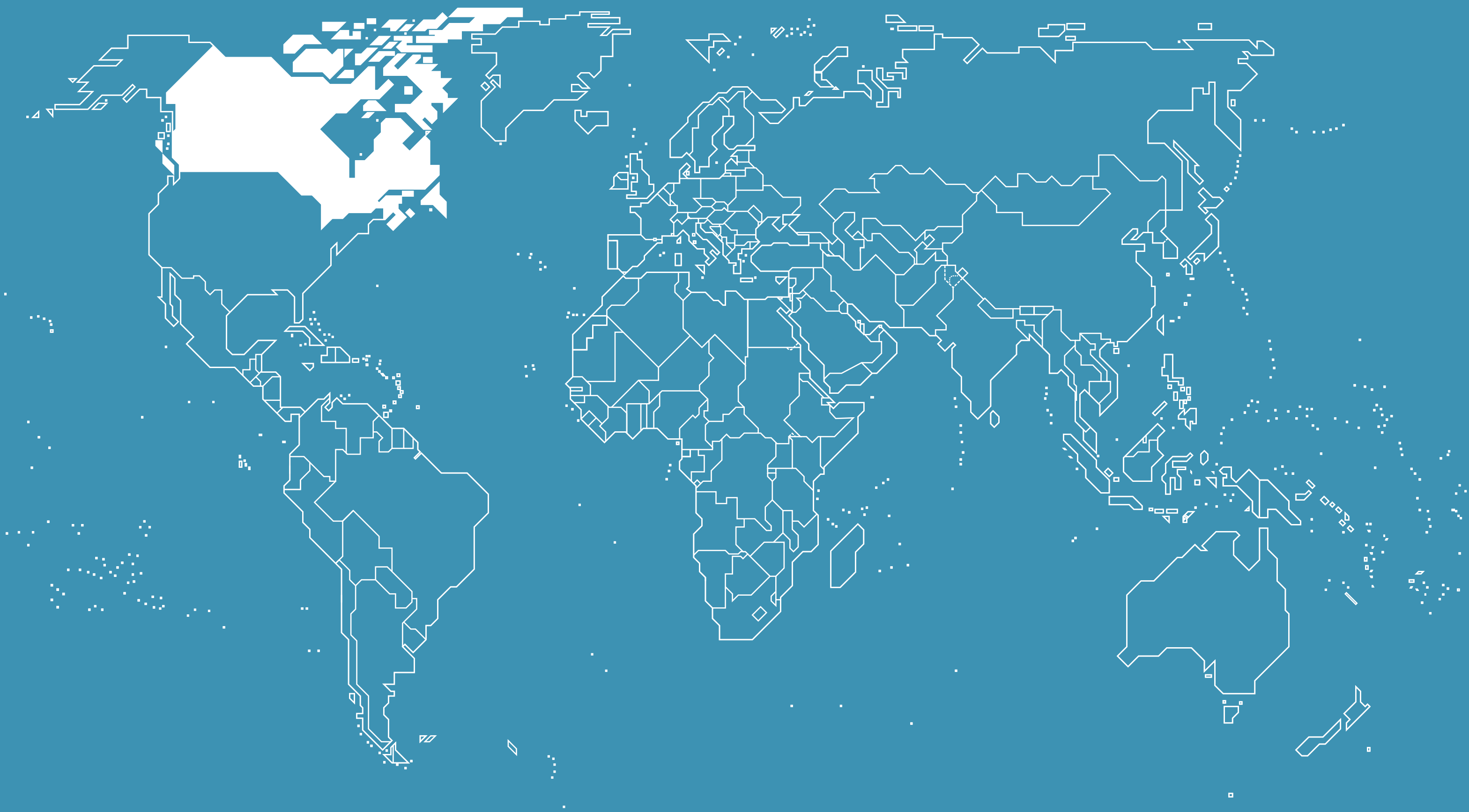
Yaoundé sanitation master plan : by SOGREAH Grenoble, France, for Ministry of Mines, Water and Power – Cameroon – Financial sponsor: African Development Bank

Regional Water resources and environmental management – JICA – Japan

« Technologies appropriées pour l'alimentation en eau et l'assainissement » par J.M Kalbermatten, D.S. Julins, C.G Gunnerson, Banque Mondiale (World Bank), 1982, also « Ecological sanitation » par Steven A Esrey, Jean Gough, etc de la Swedish International Development Coopération Agency



Canada

Biosolids – A Canadian overview

SUMMARY

There are more than 4,000 sewage treatment facilities across Canada operated by or for approximately 3,000 municipal organizations ranging from rural villages to major urban centres. The treatment ranges from simple collection systems with discharges of untreated but screened effluents directly to receiving bodies of water, to sophisticated tertiary level treatment plants. Regulatory control over these facilities is essentially provided by the environmental agencies of the 13 Provincial and Territorial Governments. Federal legislation applies to two aspects of wastewater management — management of toxic substances and deleterious wastes — predominately from the liquid phase of the treatment process. In addition, federal authority for wastewater management applies directly in areas of federal responsibility – i.e., on federal lands and properties including First Nations. The legislative framework at each level of government varies from jurisdiction to jurisdiction as do the policies that are applied. Consequently there are no national statistics available on municipal wastewater services, and even those available from some of the provincial or territorial government organizations are limited. Macro-estimates of the total production of sludges and biosolids and their uses have been made, but these are relatively crude.

Public awareness and understanding of, and attitudes towards, wastewater management vary across the country, and are particularly evident in attitudes towards the beneficial uses of municipal sewage sludge refined to biosolids. Several environmental groups have encouraged negative public attitudes, while others recognize the environmental benefits of these products.

Efforts are being made to improve the situation by coordinating research and improving the science base for management programs, taking into account that these residuals represent an environmentally beneficial resource that is currently neither generally appreciated, nor necessarily used in an optimal environmental manner. A more harmonized legislative and policy framework across the country for management of biosolids is seen as an important objective by the wastewater industry and advocates of sustainable environmental practices.

BACKGROUND

Historically, sewage sludge has been considered a waste – to be somehow disposed of and generally at the least cost possible at that. Technology has improved processing of municipal sewage sludge for beneficial use as biosolids (dewatered and/or incinerated, or dewatered and processed) to provide composted materials or soil-enhancing mixtures that can be rich in plant nutrients.

Unfortunately, this traditional philosophical view remains significant in Canada, permeating many of the smaller municipal wastewater treatment agencies and their governing regulatory community. Public perceptions have been influenced by the action of some environmental groups that seek self-serving adverse headlines. As a result, a rational discussion of biosolids has been denied us, and much of what discussion there is ignores the result of science-based studies. The consequence is that biosolids are not yet generally recognized in Canada as a valuable environmental resource, and a resource that can contribute to a number of environmental sustainability efforts, not the least of which is greenhouse gas reduction.

Beneficial decisions at the political level are difficult to obtain because biosolids and their potential beneficial uses are not a policy priority. Organic residuals of toilet flushing, an activity that every Canadian performs several times a day, are not "sexy" enough to warrant much attention. Suffice it to say that vast sums of money are spent on infrastructure to improve the final products from wastewater treatment plants, only to be paid for again to land fill rather than use. In economic models, the biosolids are "free" resources, and are available for use. Compare this to ethanol generation programs, which require huge investments in corn production, harvesting and transportation to ethanol plants, and which is now being subsidized by senior levels of government.

The current biosolids regulatory frameworks remain as barriers to progress, and these are not readily changed without political support and the will to do so. Some progress is being made by municipalities acting under severe constraints and with little support from senior levels of government to advance the cause of beneficial uses of biosolids.

LEGISLATIVE AND POLICY FRAMEWORKS

General

Jurisdiction over the activities of municipal [water and] wastewater systems resides with the municipality's province or territory. Although there is a broad similarity in legislation and policy frameworks, there remains considerable variation in details. Overlaid on this, there is a direct federal responsibility for legislation and policy applicable to what is referred to as federal lands and properties – including for example, National Parks, National Defence Properties (military bases), Federal Penitentiaries and the lands of Canada's aboriginal communities known generally as First Nations Lands.

Cooperative efforts between the federal and provincial/territorial levels of government take place for the development of Guidelines for Canadian Drinking Water Quality. Similarly, through an organization known as the Canadian Council of Ministers of the Environment (CCME), various guidelines have been developed applicable in the general area of environmental quality (atmospheric emissions, environmental water quality, hazardous sites, etc.)

In addition, Canada has a robust standardization program shared between four standards-writing bodies under the auspices of the Standards Council of Canada. One of these, the Bureau de normalisation du Québec has developed a national standard for biosolids quality.

Canadian Council of Ministers of the Environment

Recently, the CCME has published a National Municipal Wastewater Effluents Strategy that proposes to establish national performance standards for the quality of wastewater effluent discharged to the environment. It is recognized that there is a need for work in the area of the biosolids that are generated by wastewater treatment plants, and it is possible that work will begin in this area shortly. In the meantime, municipalities have proposed the development of a Canadian Biosolids Partnership of the three levels of government and other stakeholders to develop science-based information, coordinate research, and provide public information materials that would encourage the beneficial uses of organic residuals (biosolids).

In 2005, the CCME published the *Guidelines for Compost Quality*. The guidelines are based on the following four criteria for product safety and quality: foreign matter, maturity, pathogens, and trace elements. The document attempts to integrate the concept that exposure is an integral part of risk by establishing two grades of material (Category A – Unrestricted and Category B – Restricted). The guidelines are intended to protect public health and the environment and help composting continue to develop as an important resource/waste management solution. *http://www.ccme.ca/assets/pdf/compostgdlns_1340_e.pdf*

Bureau de normalisation du Québec

In 2007, the Bureau de normalisation du Québec (BNQ) was mandated to revise the Standard CAN/BNQ 0413-400 Organic Soil Conditioners – Granulated Municipal Biosolids. A Draft Standard has been prepared by a standard development committee representing the interests of producers, users and other experts. The draft is now being subjected to a public enquiry to improve the document and obtain consensus of the various stakeholders. Information on BNQ standards can be found at: *http://authorities.ca/database/Standard.asp?std=2496*.

A brief description of the federal and provincial legislation applicable to these materials follows:

Federal legislation

Canadian Food Inspection Agency

Fertilizer Act – An Act that governs agricultural fertilizers in Canada, i.e. sets out prohibitions of import and selling unless in conformity with the regulations which cover registration, use of forms and the composition, packaging and labelling, sampling and analyzing, safeguarding, and disposition), as well as powers of enforcement, ant the offences and penalties. *http://laws.justice.gc.ca/en/F-10/239332.html*

Fertilizer Regulations – Regulate and control the registration, form and composition, packaging and labelling, sampling and analyzing, safeguarding, disposition of fertilizers and supplements. Schedule II: Names and Standards of Fertilizers and Supplements, Class 1: Nitrogen Products, 1.19: Designated name: Processed sewage, Composition: Products made from sewage, freed from grit and coarse solids, that are dried, ground and screened. *http://laws.justice.gc.ca/en/F-10/C.R.C.-c.666/109185.html#rid-109190#*

Environment Canada

Canadian Environmental Protection Act, 1999 – Requirements under CEPA for reporting, for developing guidelines, codes of practice, best management practices etc. may apply although they do not specifically refer to sewage sludge, biosolids, compost, organic residuals etc. Reporting programs such as the National Pollutant Release Program (NPRI) can affect biosolids management. *http://www.ec.gc.ca/CEPARegistry/the_act/*

Fisheries Act (R. S., 1985, c. F-14) as administered by Environment Canada – The Act is not explicit about biosolids, manure etc. but under Section 36(3) any addition of deleterious substances to water can apply to disposal or environmental impact from other sources. *http://laws.justice.gc.ca/en/F-14/text.html*

Canadian Environmental Assessment Act (1992, c. 37) – An environmental assessment could be required for a project, under specific circumstances. These include if a federal permit was needed, if federal funding was received, if the project is involving federal lands, or if the federal government is completing part of the project. *http://laws.justice.gc.ca/en/C-15.2/index.html*

Alberta legislation

Alberta Environment

Environmental Protection and Enhancement Act, E12, 1996 – The purpose of this Act is to support and promote the protection, enhancement and wise use of the environment. In this Act "wastewater system" means a system for collecting, treating and disposing of wastewater and includes wastewater sludge treatment and disposal facilities. *http://www.qp.gov.ab.ca/documents/acts/E12.cfm*

Activities Designation Regulation 276/2003 – Consolidated up to 113/2006 – The Code of Practice for Wastewater Systems Using a Wastewater Lagoon only applies to the activities listed in item (d) of Schedule 2, Division 2 of the Activities Designation Regulation. The Code of Practice addresses all portions of the wastewater system including the wastewater collection system, lift station, wastewater lagoon, treated wastewater disposal via direct discharge or irrigation, and sludge application to agricultural land. The Code of Practice does not apply to aerated lagoons, storm drainage systems or snow disposal sites. Requirements for storm drainage systems are presented in the Wastewater and Storm Drainage Regulation (Sections 2-7). *http://canlii.org/ab/laws/regu/2003r.276/20070312/whole.html*

Waste Control Regulation – The Environmental Protection and Enhancement Act (EPEA) deals with the management and control of waste in various provisions, and provides Alberta Environment with the ability to address hazardous waste matters through regulations. Hazardous recyclables are dealt with through use of provisions related to the recycling of material as designated by regulation, and the control of waste (formerly litter) is dealt with in regulations as well as through the Act. *http://www.qp.gov.ab.ca/Documents/REGS/1996_192.CFM*

Code of Practice for Compost Facilities – The Code of Practice for Compost Facilities is incorporated by the Waste Control Regulation (A.R. 192/96), under the authority of section 36 of the Environmental Protection and Enhancement Act. Persons responsible for Class I compost facilities accepting 20,000 tonnes or less of waste per year must meet all its requirements to ensure that their activities are in compliance with Alberta's environmental laws. In addition to the requirements of this Code of Practice, these persons responsible must comply with all requirements of the Environmental Protection and Enhancement Act, its associated regulations, the Subdivision and Development Regulation (A.R. 212/95), and all other applicable laws. *http://www.qp.gov.ab.ca/documents/codes/COMPOST.cfm*

Wastewater and Storm Drainage Regulation – These regulations set out the requirements for wastewater and storm drainage systems. They also adopt the Code of Practice for Wastewater Systems Using a Wastewater Lagoon (see below), the Code of Practice for Wastewater Systems Consisting Solely of a Wastewater Collection System. *http://www.qp.gov.ab.ca/documents/regs/1993_119.cfm*

Code of Practice for Wastewater Systems Using a Wastewater Lagoon – The Code of Practice regulates most aspects of wastewater systems served by a wastewater lagoon including: collection, treatment, treated wastewater disposal through direct discharge or irrigation, and application of sludge to agricultural land. *http://environment.gov.ab.ca/info/library/7136.pdf*

Substance Release Regulation (AR 124/93 Air Emissions) – refers to prohibited debris such as animal manure. *http://www3.gov.ab.ca/env/protenf/legislation/factsheets/substrel.html*

Agriculture, Food and Rural Development

Agricultural Operation Practices Act – AOPA sets out clear environmental standards for all livestock operations in Alberta. Amendments to the Agricultural Operation Practices Act (AOPA) were proclaimed on January 1, 2002, launching a new standard for environmental management in Alberta's livestock industry. Further amendments based on a targeted review of the legislation were made in 2004 and are detailed in this guide. The amendments clarify and enhance the province's ability to deal with nuisances such as odour, noise, dust, smoke or other disturbances resulting from an agricultural operation. AOPA lays out clear manure management standards for all farming and ranching operations in Alberta. It also provides producers and other stakeholders with a one-window process for siting new and expanding confined feeding operations (CFOs).

Full text: http://www.canlii.org/ab/laws/sta/a-7/index.html

Guidance document: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw8746?opendocument

British Columbia legislation

Ministry of Environment

Environmental Management Act (1996) – This act defines organic material as from residential, commercial or institutional sources capable of being composted, or is being composted, at a site; as a recyclable material. Under the EMA only introductions of waste from "prescribed" industries, trades, businesses, operations and activities require authorization. Industries, trades, businesses, operations and activities are prescribed via the Waste Discharge Regulation. If an industry, trade, business, activity or operations is not prescribed by the regulation they do not require an authorization to introduce waste into the environment; however, they must not cause pollution EMA section 6(4). *http://www.qp.gov.bc.ca/statreg/stat/E/03053_00.htm*

Municipal Sewage Regulation – This regulation sets out the design, management and discharge requirements for municipal sewage systems. *http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/129_99.htm*

Organic Matter Recycling Regulation, 18/2002; amendments 321/2004 – The Regulation governs the production, quality and land application of certain types of organic matter. In the past, this organic matter have been predominantly burnt, buried or otherwise disposed of. It applies to the construction and operation of composting facilities and the production, distribution, storage, sale and use or land application of biosolids and compost. *http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/18_2002.htm#*

The Compost Facility Requirements Guideline: How to Comply With Part 5 of the Organic Matter Recycling Regulation, 2004 – The Compost Facility Requirements Guideline: How to Comply With Part 5 of the Organic Matter Recycling Regulation (OMRR) is intended as a companion document of the OMRR. The intent of this Guideline is to assist waste generators, the general public, qualified professionals, compost producers and/or facility owners and Ministry staff in understanding and/or complying with the conditions established in Part 5. *http://www.env.gov.bc.ca/epd/epdpa/mpp/pdfs/compost.pdf*

Ministry of Health

Health Act – A common sewer or system of sewerage must not be established or continued unless there is maintained with it a system of sewage purification and disposal that removes any menace to public health, and the minister may call for, and any municipal council, person or corporation must, when requested, provide as soon as possible, the information and data in relation to the matters under their control as the minister may consider necessary. *http://www.qp.gov.bc.ca/statreg/stat/H/96179_01.htm#section25*

Sewerage System Regulation – This Regulation addresses the disposal of sewage from onsite systems, as well as the installation, maintenance and inspection of these systems. *http://www.qp.gov.bc.ca/statreg/reg/H/Health/326_2004.htm*

Manitoba legislation

Manitoba Conservation

The Environment Act, E125, 1998 – The intent of this Act is to develop and maintain an environmental management system in Manitoba which will ensure that the environment is maintained in such a manner as to sustain a high quality of life, including social and economic development, recreation and leisure for this and future generations. For the purpose of carrying out the provisions of this Act according to their intent, the Lieutenant Governor in Council may make regulations and orders respecting the design, construction, adaptation, alteration, operation, maintenance and installation of systems, processes or works to abate or control pollution or other environmental damage including but not limited to waste disposal grounds, landfills, sewage collection and treatment, sewage or industrial sludge handling and disposal, incinerators, and recycling systems. *http://web2.gov.mb.ca/laws/statutes/ccsm/e125e.php*

Livestock Manure and Mortalities Management Regulation – The purpose of this Regulation is to prescribe requirements for the use, management and storage of livestock manure and mortalities in agricultural operations so that livestock manure and mortalities are handled in an environmentally sound manner. *http://www.gov.mb.ca/conservation/pub-archive/publs98/manure.html*

Onsite Wastewater Management Systems Regulation – This Regulation sets out the standards for the disposal of sewage from onsite systems. The disposal on the ground is allowed if certain conditions are met. *http://web2.gov.mb.ca/laws/regs/pdf/e125-083.03.pdf*

Ministry of Agriculture and Lands

The Farm Practices Protection Act – The protection provided by the Act specifically relates to nuisances such as odour, noise, dust or other disturbances. *http://web2.gov.mb.ca/laws/statutes/ccsm/f045e.php*

New Brunswick legislation

Ministry of the Environment

Clean Environment Act – This Act talks primarily about general waste disposal. *http://www.gnb.ca/0173/30/Fertility%20guide%202001.pdf*

Clean Environment Act, Guidelines for the Site Selection, Operation and Approval of Composting Facilities in New Brunswick – The aim of these guidelines is to provide some basic information on the composting process as well as to offer guidelines relating to the siting and operation of composting facilities in the province. These guidelines will help ensure that compost can be produced without adversely affecting human and animal health, food production and the natural environment. *http://www.ecolog.com/solidwaste/print.asp?doc_id=nb_b16*

Water Quality Regulation – The Regulation gives the Minister the authority to give an order to control or end any release into the environment. *http://www.gnb.ca/0062/regs/82-126.htm*

Newfoundland and Labrador legislation

Environment and Conservation

Environmental Protection Act – The Act includes definitions for waste and compost, and gives the Minister the authority to make regulations regarding composting practices. *http://assembly.nl.ca/Legislation/sr/statutes/e14-2.htm*

Northwest Territories legislation

Department of Environment and Natural Resources

Environmental Protection Act – The Act bans the release of substances into the environment unless the discharge meets certain criteria, including if it is allowed under a Regulation. Section 2.2 of the Environmental Protection Act (EPA) gives the Minister of Resources, Wildlife and Economic Development the authority to develop, co-ordinate and administer guidelines. *http://www.justice.gov.nt.ca/PDF/ACTS/Environmental_Protection.pdf*

Guideline for Agricultural Waste Management – The purpose of this guideline is to establish clear and consistent waste management standards for the Northwest Territories' intensive livestock and agricultural industry. This guideline has been developed by the Environmental Protection Service of the Department of Resources, Wildlife and Economic Development in conjunction with the Territorial Farmer's Association, taking into consideration northern conditions. *http://www.enr.gov.nt.ca/library/pdf/eps/agriculturalwastefinal.pdf*

Guideline for Industrial Waste Discharges – The purpose of this guideline is to establish standards that should be followed in the discharge of waste from an industrial operation on Commissioner's Land or lands administered by municipal governments in the Northwest Territories (NWT). It is also intended to:

- provide direction for the management and discharge of industrial waste;
- protect the environment;
- protect municipal infrastructure, such as sewage systems and solid waste modified landfills, from immediate and long term environmental problems; and
- protect workers and the public from improper industrial waste discharge.

http://www.enr.gov.nt.ca/library/pdf/eps/inudstrialwastedischarges.pdf

Health and Social Services

Public Health Act – The Act gives the Minister the authority to develop regulations necessary for the prevention and mitigation of disease and the promotion and preservation of health in the Territories, including respecting the location, construction, ventilation, inspection, cleansing and sanitary control of sewers, sewage systems, water closets, indoor and outdoor toilets, lavatories, cesspools, soakage pits, septic tanks and pumps. *http://www.justice.gov.nt.ca/pdf/acts/Public_Health.pdf*

Public Sewerage Systems Regulations – Regulations governing sewage discharges. They require systems be designed to provide for adequate protection of the receiving water. *http://www.justice.gov.nt.ca/pdf/regs/Public_Health/Public_Sewerage_Syst.pdf*

Nova Scotia legislation

Environment and Labour

Environment Act – The purpose of this Act is to support and promote the protection, enhancement and prudent use of the environment. The Act requires the Minister to establish fees for emission and effluent discharge levels, the provision or filing of any information, documents, returns and reports, any application for, processing and issuance of an approval, a registration or a certificate, any inspection or investigation, any services or material provided and any other matter respecting the administration of this Act. The Minister may also prescribe methods and procedures for sampling and analysis of the environment and any substance, discharge or emission into the environment. He may also make regulations regarding discharges. *http://www.gov.ns.ca/legislature/legc/statutes/envromnt.htm*

Activities Designation Regulations – Any activity designated in these regulations requires an approval from the Minister or an Administrator designated by the Minister. Included are: the construction or reclamation of a sewage works, a storm drainage works, septage works including treatment and disposal facilities and the application to land of non-livestock generated wastes, wastewater and wastewater sludge. *http://www.gov.ns.ca/legislature/legc/statutes/envromnt.htm, http://www.gov.ns.ca/just/regulations/regs/envactiv.htm*

Solid Waste-Resource Management Regulations – These regulations place restrictions on composting activities. *http://www.gov.ns.ca/just/regulations/regs/envsolid.htm*

Ontario legislation

Ministry of Agriculture, Food and Rural Affairs

Nutrient Management Act – The Nutrient Management Act and its Regulation 267/03 address land-applied materials containing nutrients. This includes provisions for the development of strong new standards for all land-applied materials containing nutrients, a proposal to ban the land application of untreated septage over a five-year period, and proposed strong new requirements such as the review and approval of nutrient management plans, certification of land applicators and a new registry system for all land applications. *http://www.omafra.gov.on.ca/english/crops/field/news/croptalk/2003/ct_1103a3.htm*

Nutrient Management Protocol – Provides technical and scientific details and standards that are complementary to, and in addition to, those set out in the Regulation. This Protocol will be useful in developing and implementing nutrient management strategies and nutrient management plans that comply with regulatory requirements. *http://www.omafra.gov.on.ca/english/nm/regs/nmpro/nmpro01j05.htm*

Sampling and Analysis Protocol for Soil and Land Applied Materials – Proper sampling and analytical techniques are critical to accurately determine the nutrient content and other properties of materials. This has always been important but has now become a legal requirement under the Nutrient Management Act, 2002. The techniques described in this document are intended to meet the requirements of the regulations under the Act. They can also provide guidance for other sampling and analysis requirements with similar goals. *http://www.omafra.gov.on.ca/english/nm/regs/sampro/samproj07.pdf*

Guidelines for the Utilization of Biosolids and Other Waste on Agricultural Land – The purpose of this document is to facilitate the use of biosolids and other waste materials on agricultural land, while protecting environmental quality, consumer and animal health, food quality and the productivity of the land. These Guidelines are intended to supplement Ontario Regulation 347 under the Environmental Protection Act.

The document outlines criteria which must be met before biosolids or other waste materials can be considered for use on agricultural land. In essence, these materials must be of benefit to crop production or soil health and not degrade the natural environment, before approval for use will be given by the Ministry of Environment (MOE). The materials should supply essential plant nutrients and/or organic matter, or other constituents that will maintain crop production or soil health.

For clarification, the term sewage biosolids refers to stabilized municipal "sewage sludge" as included in Processed Organic Waste, in Ontario Regulation 347. Hauled sewage (septage) is not included in this category. The term "other wastes" includes materials not defined as sewage biosolids, septage or agricultural waste in Ontario Regulation 347. The term "waste materials" is used frequently in this document and refers to both sewage biosolids and other wastes. *http://www.ene.gov.on.ca/envision/gp/3425e.pdf*

Ministry of Environment

Environmental Protection Act – The purpose of this Act is to provide for the protection and conservation of the natural environment. *http://www.omafra.gov.on.ca/english/nm/nasm/nms/completing.htm*

General Waste Management Regulation – These Regulations set standards for the location, maintenance and operation of an organic soil conditioning site including processed organic waste. *http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_900347_e.htm*

Guide for Applying for a Certificate of Approval to Spread Sewage and Other Biosolids on Agricultural Lands (Organic Soil Conditioning) [Sewage Biosolids and Other Wastes] – This document is intended to provide guidance to proponents of waste disposal facilities (sites and systems), when requesting approval of those facilities under Section 27 of the Environmental Protection Act, R.S.O. 1990, Chapter E-19, (EPA). This document describes the approvals process in general, clarifies the information required by the respective application form and specifies the technical information that may be required in support of the application.

The statutory requirement for a Certificate of Approval for a waste disposal site is contained in Section 27 of the EPA. Section 27 requires that approval be obtained from the Director before using, operating, establishing, altering, enlarging or extending a waste management system or a waste disposal site. *http://www.ene.gov.on.ca/envision/gp/4182e01.pdf*

Prince Edward Island legislation

Ministry of Environment and Energy

Environmental Protection Act – The Act prohibits the establishment of a waste treatment system or water supply system, or change to any existing system, without written approval from the Minister. *http://www.gov.pe.ca/law/statutes/pdf/e-09.pdf*

Sewage Disposal Systems Regulations – The Regulations require approval before a person engages in the cleaning of a sewage disposal system or a wastewater treatment system, or in the land spreading of septage or sludge, unless the person first obtains a pumper's licence from the Minister; and complies with the provisions of these regulations. *http://www.irac.pe.ca/legislation/EPA-SewageDisposalSystemsRegulations012505.asp*

Québec legislation

Ministère du Développement durable, de l'Environnement et des Parcs du Québec

Loi sur la qualite de l'environnement – Overriding legislation giving the Minister the authority to develop guidelines or regulations concerning biosolids. *http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=/Q_2/Q2.htm*

Guidelines for the Beneficial Use of Fertilizing Residuals (FR) and Addendum 2006 – These new guidelines, which include the applicable standards and criteria, will be used to determine whether a certificate of authorization is required for the reclamation of specific fertilizing residuals. The context for the reclamation of FRs is outlined beginning in Section 2, which provides general information on fertilizing residuals, and Section 3, which presents the main regulatory bodies. An addendum describes modifications made in February 2006 to the pathogen criteria, as well as the sampling of FR by accredited firms. Justification and expected impacts are presented. The modifications described in this addendum are applicable to all certificates of authorization applied for as of February 15, 2006, Standards: CAN/BNQ 0413-200 – Organic Soil Conditioners – Composts CAN/BNQ 0413-400 – Organic Soil Conditioners – Granulated Municipal Biosolids.

Fertilizing Residuals are "residual materials that can be used to maintain or improve, separately or simultaneously, plant nutrition, as well as the physical and chemical properties and biological activity of soils." This definition combines the expression "residual materials," as defined in section 1 of the *Environment Quality Act (EQA)*, and the concept of "fertilizers and soil conditioners," as defined by the International Organization for Standardization (ISO, 1984). *http://www.mddep.gouv.qc.ca/matieres/mat_res-en/fertilisantes/critere/guide-mrf.pdf*

Saskatchewan legislation

Agriculture and Food

Agricultural Operation Practices Act – Lays out clear manure management standards for all farming and ranching operations in Saskatchewan. It also provides producers and other stakeholders with a one-window process for siting new and expanding confined feeding operations (CFOs).

Saskatchewan Environment

Environmental Protection and Management Act – The Act requires a person to obtain a permit to construct, extend or alter a sewage or waterworks. The Minister may then place restrictions on the project, within the permit.

Water Regulations 2002 – Set out the construction, operation and maintenance requirements for water and sewage works in the province.

Guidelines for Sewage Works Design – Except for industrial wastewater works, the design guide applies to all sewage works described in the Water Regulations, 2002 and should be used as a companion to the applicable Acts. The Guideline refers to the process of treating and disposal methods for sludge.

Saskatchewan Water and Wastewater Works Operator Certification Standards, 2002 – This document sets out the standards for the classification of water and wastewater works and the qualifications for the certification of the operators of those facilities. They state that the land application or beneficial reuse of biosolids by a contractor outside of the control of the operator in direct responsible charge of the wastewater treatment facility.

Note: URLs for the Saskatchewan legislation are not available.

Yukon legislation

Yukon Environment

Environment Act – General provisions on the disposal of wastes. *http://www.gov.yk.ca/legislation/acts/environment.pdf*

Macro data estimates

In 2002, CWWA undertook a national survey of municipal wastewater utilities seeking information on the production of biosolids. At that time, it was estimated on the basis of replies from more than 40 utilities, that approximately 550,000 tons of biosolids and composts were produced. There are many other municipalities that generate organic residuals but there is no means of collecting this data. Accordingly an alternative approach was recently taken to estimate the potential production of these materials.

According to Environment Canada's *Municipal Water Use Statistics, 2004*[1], 24 million Cana-

1 *2007 Municipal Water Use Report – Municipal Water Use – 2004 Statistics, Environment Canada, Table 5, http://www.ec.gc.ca/Water/en/info/pubs/sss/e_mun2004.pdf*

dians were connected to municipal sanitary sewers and the total flow through the sewers averaged 651 L/p/day. According to surveys done in the USA by the USEPA in 1999[2] and the North East Biosolids and Residuals Association (NEBRA) in 2004[3], a reliable relationship can be calculated between the generation and treatment of wastewater (in MGD) and the production of dry biosolids. In the NEBRA report, it was stated that for a national flow of 34,201 MGD – 7,189,000 tons of dry biosolids were produced, used or disposed.

Converting the Environment Canada figures of flows through sanitary sewers and using the conversion factors from the US, indicates that Canada could produce more than 860,000 tons of dry biosolids annually[4].

As mentioned, the CCME proposed National Municipal Wastewater Effluent strategy is expected to come into force in 2009. CWWA has advised the CCME that the current amount of biosolids production will increase as the Strategy is implemented and as more and more Canadians are connected to municipal sewer systems.

Sector activities and uses

Based on the 2002 CWWA survey of 50 utilities producing biosolids, around one-third of their production is land applied, one-third is incinerated (sometimes for energy recovery) and one-third is simply land filled. However it is noted that the non-surveyed and non-reported sludge production from smaller utilities is generally either land applied or sent to land-fill which would increase the proportion for land applications and for land-fill disposal above the one-third level and reduce the proportion incinerated.

This is not similar to indications of US biosolids use where the EPA[5] report indicated that 52% of biosolids was land applied, 22% was incinerated and 17% went to land fill, with the remainder going to other uses. The disposition in millions of tons and percentages is shown in the following table:

Beneficial Uses				Disposals				Total
Land Application	Advanced Treatment	Other Beneficial Uses	Total	Surface Disposal/ Landfill	Incineration	Other	Total	
3.6	0.07	0.5	4.1	1.2	1.5	0.07	2.8	6.9
52%	1%	7%	60%	17%	22%	1%	40%	100%

NEBRA[6] estimates that in 2004, production had reached 7.2 million dry tons and reported only a gross breakdown between beneficial uses – land application (49%) – and nonbeneficial uses — disposal (45%) – with the remaining 6% going to long-term storage or other uses.

It is known that in Canada untreated wastewater sludge can still simply be land-applied (sometimes under provincial control, sometimes without control) or sent to land fills, although this activity is diminishing. Treated sludges are incinerated either with or without energy r o, best management practices; further improvement of knowledge of biosolids through innova-

2 *Biosolids Generation, Use and Disposal in the United States, US EPA, September, 1999, EPA530-R-99-009, – www.epa.org*
3 *A National Biosolids Regulation, Quality, End Use and Disposal Survey, Final report, July 20, 2007, North East Biosolids and Residuals Association (NEBRA) – www.nebiosolids.org, Table 2.*
4 *This is a crude estimate only, and much depends on levels of treatment provided and the extent of the sludge processing and dewatering performed.*
5 *Ibid*
6 *Ibid*

tion and research; and improved communication with government and stakeholders by promoting education and awareness. The CWWA has agreed to provide the initial secretariat and administrative support to the CBP.

At the forefront of discussion and concern amongst many Canadian citizens are the impacts of climate change and air quality in general. This sentiment is reflected in the Government of Canada's commitment to mitigating climate change by reducing greenhouse gas (GHG) emissions and improving air quality, as evident by the ongoing development of the proposed *Canada's Clean Air Act* and the subsequent Notice of Intent to Regulate Greenhouse Gas Emissions by Large Final Emitters. As a party of the United Nations Framework Convention on Climate Change, Canada has agreed to a number of commitments to reduce GHG emissions. Among these commitments are the development of GHG mitigative technologies and sinks.

Beneficial uses of biosolids hold great potential as a significant component of activities and technologies to reduce GHG emissions and sequester atmospheric carbon. Biosolids have been used in forest fertilization, reforestation and afforestation to facilitate biomass production and soil development – two mechanisms for immediate carbon sequestration. As a fertilizer alternative, biosolids use reduces dependencies on chemical fertilizers derived from fossil fuels or from geological sources. Recent research has provided evidence that biosolids can be used as a component of fabricated soils that reduce fugitive methane emissions from closed landfills. Furthermore, beneficial use of biosolids precludes their disposal in lan dfills or incineration; both of these management options are sources of GHG and air pollutant emissions.

Municipalities continue to believe that the establishment of the CBP will lead to improved communication between Canadian biosolids generators and experts and continued investigation of GHG mitigative technologies using biosolids. Furthermore, the beneficial uses of biosolids identified and described provide municipal governments and regional districts nationwide with the opportunity to be a partner in projects related to GHG emission reductions and climate change mitigation. Although these activities are consistent with the commitments the Government of Canada has made to reducing GHG emissions the use of biosolids in reducing GHG emissions and sequestering atmospheric carbon is a technology that is not yet recognized in federal or provincial environmental policies and programs.

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7 *The Canadian Water and Wastewater Association (CWWA) is a national, nonprofit organization representing public sector water and wastewater treatment works in Canada. Formed in 1986, the CWWA has been the catalyst in the formation of a national water and wastewater treatment network. Working with federal and national bodies and all levels of government, the CWWA participates in the development of water and wastewater policies and regulations, supports and encourages research and technology transfer, and builds relationships with stakeholders through communication, education and awareness.*

8 *Curry Jefferson and Associates Environmental Services Inc. is a member of CWWA and active in the area of wastewater management and biosolids.*

Greater Moncton Sewerage Commission (GMSC)

INTRODUCTION

This contribution has been submitted by the Greater Moncton Sewerage Commission (GMSC) located in Riverview, New Brunswick, on the East Coast of Canada.

The GMSC was formed in 1983 by the Province of New Brunswick in consultation with the City of Dieppe, City of Moncton and Town of Riverview. Its mandate was to undertake the design and construction of a wastewater collection and treatment system in order to eliminate the direct discharge of raw wastewater from the three municipalities to the Petitcodiac River. This river is part of the Bay of Fundy system which is known for one of the highest tides in the world – up to 10 m.

The current wastewater-conveying and -treatment assets of the GMSC consist of 30 kms of collection sewers and tunnels, eight (8) sewage lift stations, one (1) large automated pumping station (capacity 265 000 m^3/d) considered the largest of its kind in Atlantic Canada, and a modern Wastewater Treatment Facility.

Located in Riverview, this 115 000 m^3/d Wastewater Treatment Facility provides screening, grit removal, advanced chemically assisted primary treatment to meet provincial guidelines for effluent BOD (12 700 kg/d) and suspended solids (7600 kg/d) utilizing three large circular flocculation type clarifiers with integral picket thickening, raw sludge dewatering via high solids handling centrifuges, lime stabilization of raw sludge and odour control facilities using wet scrubbers and biofilters.

Effluent disinfection is not required under the current provincial regulatory agency Certificate of Approval. The current serviced population is approximately 100 000 with average daily flow for 2007 of approximately 66 000 m^3/d. The raw sewage BOD and TSS are 202 mg/L and 173 mg/L respectively. Considerable septage is also handled at the plant.

The GMSC has an existing biosolids beneficial use program which is integrated, sustainable and cost-effective. The GMSC currently operates a biosolids management program – a function of the Wastewater Treatment Facility.

The GMSC has recently completed the construction of a biosolids composting facility to move forward the treatment facility biosolids management program.

The GMSC produces approximately 11 000 wet tonnes per year of biosolids, (2600 dry tonnes of lime-stabilized biosolids). The composting process used by the GMSC combines bottom aeration and a proprietary cover system referred to as the GORE™ Cover System.

SELECTION OF DISPOSAL PRACTICE

Table 1 provides the analysis comparisons of the benchmark sludge/biosolids with the GMSC results and Province of New Brunswick limits for direct land application.

Table 1. Benchmark sludge/biosolids compared to GMSC results and Province of New Brunswick limits

	Benchmark Sludge/ Biosolids	GMSC Samples[1]	Province of New Brunswick (Max. Acceptable Limits)
Dry Solids	6% w/w	30 w/w	—
Organic Matter	75% w/w	55 w/w	—
Zinc	1000 mg/kg	223 mg/kg	1850 mg/kg
Copper	500 mg/kg	137 mg/kg	850 mg/kg
Nickel	40 mg/kg	9 mg/kg	180 mg/kg
Mercury	3 mg/kg	0.3 mg/kg	5 mg/kg
Cadmium	3 mg/kg	0.5 mg/kg	20 mg/kg
Lead	200 mg/kg	27 mg/kg	500 mg/kg
Total Nitrogen	3.5% w/w	2.1 w/w	—
P_2O_5	3.5% w/w	0.5 w/w	—
K_2O	0.2% w/w	0.1 w/w	—

[1] *Based on 2007 Analysis Results*

The benchmark sludge would currently meet existing Province of New Brunswick standards for both land application (of lime-stabilized biosolids) and composting. Currently the Province of New Brunswick will not approve land application of biosolids within the Province. The most favored option for the beneficial use of the benchmark sludge would be the production of Class 'A' Compost approved for unrestricted use.

In the event that land application of biosolids was approved by the Province, the land application of wastewater sludge in New Brunswick follows the "Guidelines for Issuing Certificates of Approval for the Utilization of Wastes as Soil Additives" (1996). The Guidelines cover acceptable methods of stabilization, suitability of the land where wastewater sludge may be applied, as well as application rates, separation distances, and waiting periods between the application of the wastewater sludge and various uses of the land. Only stabilized wastewater sludge could be land applied, if approval received from the Province of New Brunswick, and all methods of stabilization would be evaluated on a case-by-case basis. The Guideline limits for metals in wastewater sludge for land application are listed in Table 2. There are currently no specific guidelines for organic compounds contained in wastewater sludge.

Table 2. New Brunswick – Maximum acceptable metal concentrations

Metal	Maximum Acceptable Metal Concentration in Wastewater Sludge (mg/kg dw)	Maximum Acceptable Metal Concentration in Soil (mg/kg dw)
Arsenic	75	14
Cadmium	20	1.6
Chromium	1100	120
Cobalt	150	20
Copper	850	100
Mercury	5	0.5

Metal	Maximum Acceptable Metal Concentration in Wastewater Sludge (mg/kg dw)	Maximum Acceptable Metal Concentration in Soil (mg/kg dw)
Molybdenum	20	4.0
Nickel	180	32
Lead	500	60
Selenium	14	1.6
Zinc	1850	220

The yearly application rate is based on the heavy metal levels in the soil and wastewater sludge and the nitrogen content of the wastewater sludge. The nitrogen content must not exceed the annual nitrogen fertilizer requirement for the crop planted. If heavy metal and nitrogen restrictions are met, a maximum application rate of eight dry tones per hectare, one per three-year period, has been established for agricultural lands. All agricultural lands that are intended for wastewater sludge applications must be tested to ensure that they do not exceed the soil metals limits (Table 2).

The soil pH requirement is also specified in the guidelines. Wastewater sludge must not be applied to agricultural land where soil pH is below 6.0 or above 6.8. However, if lime or a similar material is added before or concurrently with the waste so the soil pH will be raised to a least 6.0 but not more than 6.8, to a depth of 15 cm, land application of wastewater sludge is permitted.

Over the years, the GMSC has developed several land-based resource programmes utilizing lime-stabilized biosolids, namely soil additives in agriculture, sod farming, landfill cover, open-pit mine site rehabilitation, golf courses, tree farming and the training area of Canadian Forces Base and other land reclamation projects. Planning for implementation of other uses is also in process, including the manufacturing of topsoil. Our long-term objective is to recycle our biosolids entirely within the area that the GMSC serves.

The limited period during which direct land application can be used due to seasonal conditions posed a real challenge to the day-to-day operation at the Plant. The GMSC needed to further stabilize the material for storage and handling to be nuisance-free. Consequently, over the years, the GMSC developed composting techniques to the point that it currently processes all its wastewater raw sludge to biosolids, then into compost.

As the quality of biosolids is important to obtaining public acceptability and perception, as well as long-term recycling sustainability, the GMSC has built a state-of-the-art composting facility using biosolids and waste products from the forestry industry as a bulking agent. The system combines bottom aeration and a proprietary cover system. The composting phase operates at over 55°C for extended periods of time, thus producing the highest-quality product. This facility produces Class A biosolids, which permits the GMSC unrestricted disposal or recycling options.

Best-practice procedures require that the public's concerns and perceptions are considered at the critical stage of applying biosolids on lands. Consequently we have been able to stabilize the biosolids before application to control odors so that they are not an issue. Because of our success in finding beneficial uses for our biosolids, we have, in our area, been able to change the perception of biosolids from that of a waste product to a valuable and desired product.

ECONOMIC INFORMATION

The benchmark biosolids and soil characteristics are not appreciably different from those characteristics found in the Greater Moncton Area that is served by the GMSC Wastewater Treatment Facility.

Table 3. Costs of operations	
Typical proportion of total annual costs for sewage collection and treatment attributable to biosolids	50%
Charges to customer for collecting and treating 1m^3 of wastewater is	\$0.50/ m^3 CAD (2007)
Cost of 1,000 litres of diesel fuel	\$1,200.00 CAD (2007)
Cost of one kilowatt/hour of electricity	\$0.1122 CAD – First 82,300 kwh (2007) \$0.053 CAD – Additional kwh (2007)

LANDFILL OPTION

The GMSC's integrated and sustainable biosolids management approach does not now include landfill options. The GMSC considers the biosolids produced as a product that has beneficial uses, including recycling. The biosolids are therefore not considered to be a waste for landfill. The only landfill option that would be considered would be as landfill closure cover material.

Use of biosolids as landfill closure cover material eliminates the need for large volumes of topsoil, which reduces not only the cost but also the demand on valuable topsoil normally stripped from local farms. The GMSC has had successful experience in the beneficial use of biosolids for landfill closure cover material of the former City of Moncton and Town of Sackville landfill sites. The revegetated City of Moncton landfill now incorporates a network of walking, hiking and biking trails.

INCINERATION OPTION

Incineration is not an available option in the Province of New Brunswick.

DOMESTIC USE OF BIOSOLIDS

The GMSC now processes all of its biosolids into compost in cooperation with the private sector. The lime-stabilized biosolids are composted using wood waste (bark and wood chips) as a bulking agent.

As noted in Table 4, the compost produced fully complies with established limits of the Canadian Council of Ministers of the Environment (CCME), for Class A. Compost of this quality can be used in any application, such as agricultural land, residential gardens, horticultural applications and the nursery industry.

Table 4. Concentration of trace elements in composted biosolids

Trace elements	GMSC compost* (mg.kg^{-1} dry weight)	Category A (CCME)** Maximum concentration within product (mg.kg^{-1} dry weight)
Arsenic (As)	2.3	13
Cadmium (Cd)	0.7	3
Cobalt (Co)	2.3	34
Chromium (Cr)	33.0	210
Copper (Cu)	125.0	400
Mercury (Hg)	0.4	0.8
Molybdenum (Mo)	3.6	5
Nickel (Ni)	16.7	62
Lead (Pb)	26.2	150
Selenium (Se)	B.D.L.	2
Zinc (Zn)	248.0	700

** sampling results 2007*

*** CCME (Canadian Council of Minister of Environment) revised 2005*

GENERAL AGRICULTURAL PRACTICE

The GMSC biosolids management plan currently does not include application of biosolids to agricultural practice, however the compost produced could be used effectively for increasing the soil's organic content.

Use of grazing land

The GMSC biosolids management plan currently does not include application of biosolids to beneficial use of grazing land.

Use of arable land

The GMSC biosolids management plan currently does not include application of biosolids to beneficial use of arable land.

Use of forest or wood land

The GMSC biosolids management plan currently does not include application of biosolids to beneficial use of forest or wood land.

Use on conservation or recreational land

The GMSC biosolids management plan currently does not include application of biosolids to beneficial use on conservation or recreational land.

Use on land reclamation

The GMSC biosolids management plan currently does not include application of the benchmark biosolids to beneficial use on land reclamation. However, the current GMSC biosolids management plan has a major land reclamation component. The compost is used as a soil amendment in re-establishing vegetation at a major Canadian Forces Base, in the revegetation activities at inactive gravel pit operations, open pit mine sites, landfill sites as well as other projects.

PRODUCTION OF BY-PRODUCT

The conversion of wastewater sludge from a waste product to compost suitable for unrestricted use allows the GMSC to access more markets in their biosolids beneficial use programme.

One by-product produced by the GMSC is a blended topsoil and amended topsoil for use in the Wastewater Treatment Facility service area.

As part of the sustainable development objectives, biosolids must be regarded as a recyclable resource that can be put to beneficial use. Many traditional disposal options such as landfilling and incineration are becoming less acceptable from an economic and environmental standpoint. As a result, many jurisdictions are moving quickly to develop a long-term beneficial use strategy for wastewater sludge/biosolids that is sustainable, cost-effective and environmentally acceptable. The Greater Moncton Sewerage Commission has moved in this direction with highly successful results in its management and beneficial use of lime-stabilized biosolids from the Greater Moncton Wastewater Treatment Facility.

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Ontario

Biosolids use in Canada is regulated under a number of different regulations, both federally and provincially. If biosolids are sold as a nutrient source, they come under the jurisdiction of the Federal Fertilizer Act and must comply with federal regulations for fertilizers. Biosolids use may also be subject to provincial regulation. In the province of Ontario, if biosolids are not sold, but are given away, they are considered to be waste, and are governed by several provincial regulations.

There are multiple provincial regulations and guidelines that control the use of biosolids in Ontario. Most are directed towards controlling the use of biosolids applied to agricultural land. Historically, biosolids were land applied under a Certificate of Approval (CofA) issued by the Ministry of the Environment under the Environmental Protection Act for an organic soil conditioning site. The issuance of CofA's and the practices for land application of biosolids are guided by the Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land, published by the Provincial Ministry of the Environment (MOE) and the Ministry of Agriculture, Food and Rural Affairs (OMAFRA). These guidelines become official and take on the force of regulation when they are referenced in the CofA issued by the MOE for a biosolids application site. A more recent piece of legislation, the Nutrient Management Act, is being introduced and currently mirrors the requirements of the CofA process. The intent is that the Nutrient Management Act will eventually regulate the use of all nutrients in agriculture, through the need for farm nutrient management plans. Permissible metals content in biosolids to be land applied are shown in Table 1. The regulations also ensure that biosolids cannot be applied to soil which already has elevated metals concentrations.

Table 1. Standards for regulated metals in materials applied to land that are sewage biosolids

Regulated Metals	Maximum metal concentration in material to be applied up to 22 tonnes per hectare per five years (mg / Kg of total solids dry weight)	Maximum metal concentration in material to be applied up to eight tonnes per hectare per five years (mg / Kg of total solids dry weight)	Maximum permissible metal addition to soil receiving non-agricultural source materials (Kg / Ha / 5 Years)	Maximum metal concentration in soils receiving non-agricultural source materials (mg / Kg of Soil, dry weight)
Arsenic	75	170	1.40	14
Cadmium	20	34	0.27	1.6
Cobalt	150	340	2.70	20
Chromium	1,060	2,800	23.30	120
Copper	760	1,700	13.60	100
Mercury	5	11	0.09	0.5
Molybdenum	20	94	0.80	4
Nickel	180	420	3.56	32
Lead	500	1,100	9.00	60
Selenium	14	34	0.27	1.6
Zinc	1,850	4,200	33.00	220

O. Reg. 267/03, Part IX, Table 1; O. Reg. 447/03, s. 49.

A separate set of provincial guidelines governs production of compost in Ontario. If the compost is sold, then it must also comply with Federal Fertilizer Act requirements for compost. Like the biosolids guidelines, the Ontario compost guidelines can take on the force of law when referenced in a CofA for the construction and operation of a composting facility. The Ontario compost guidelines contain very restrictive compost metals limits which essentially mirror background soil concentrations for all of the 11 metals shown in Table 1. They also contain a requirement that any feed stock going into a composting operation must meet the compost metal limits. This effectively prevents any municipal biosolids from being composted in Ontario. Some Ontario biosolids have been composted, either in neighboring provinces, or by avoiding reference to the Ontario compost guidelines in their processing CofA.

Typically, biosolids must be pasteurized through heat treatment such as pelletization or alkaline stabilization to be sold under the Federal Fertilizer**s** Act. The fertilizer act requires labeling of the fertilizer with information such as N-P-K content and intended application rates. The application rates and metals content of the fertilizer must be at a level that metals addition to soil over a 45-year period will not exceed prescribed limits.

SELECTION OF BIOSOLIDS MANAGEMENT OPTIONS

Changes at wastewater treatment plants in Ontario are regulated by several Provincial regulations. One is the Environmental Assessment Act, which requires a municipality to undertake an Environmental Assessment (EA) of any proposed project.

The EA must consider impacts on the natural, social and economic environment, and frequently must consider any alternatives to the proposed project. The assessments must be undertaken in a public process involving public notification of the proposed EA process, open houses, opportunities for public participation, a public comment period, and the opportunity for the public to request a more detailed review of impacts or alternatives. In order to help determine the alternatives that must be considered in an EA, municipalities will typically first undertake a master plan that looks at broad high-level issues and satisfies part of the requirement for an EA. Biosolids master plans are commonly completed to help a municipality decide between common options such as land application, land filling, composting, or incineration, as well as less common practices such as sale as fertilizer, land reclamation or silviculture. The biosolids master plan will also typically address issues such as the choice of biosolids stabilization process, dewatering and biosolids storage.

One of the factors that are often critical in the public process and decision making is the political acceptability of each option. While almost all options are legally available, in some areas of the province they may not be considered acceptable by part of the local population. In some cities incineration is not acceptable, even though it may be preferable from an environmental and economic standpoint. In other areas biosolids application to land is considered unacceptable, even though there is amply suitable farmland close by. These considerations are often driven by vocal local opposition, based on fear of environmental impact, or odours. This has resulted in large cities having to haul biosolids over 500 km to find available farmland or landfills. The concern over odours at rural application sites has led to a preference for liquid application by direct injection, or surface application followed by immediate incorporation. Direct injection of dewatered cake has also been used to control odours.

ECONOMIC INFORMATION

In most Ontario municipalities, users pay for water and sewage based on water consumption. In some places the cost reflects the full cost of treatment, in others the cost of treatment is subsidized by the municipal tax base. The province is moving towards full cost accounting and full user pay, including consideration of long-term infrastructure replacement costs.

- Typical proportion of wastewater treatment operations and maintenance cost attributable to solids management is ~50%
- User charge for treatment of sewage is $0.60/m^3
- Cost of 1,000 litres of diesel fuel is $1,200
- One kilowatt hour of electricity costs $0.06

POTENTIAL USES

Landfilling

To be disposed of in landfill, biosolids must typically first be dewatered. Ontario has a limited number of active large landfill sites and has tried unsuccessfully for several decades to site new landfills to service its major metropolitan area. As a result some biosolids have been shipped to neighboring provinces or countries for landfill disposal. Biosolids are typically placed into landfills along with municipal and commercial wastes. This option is generally not preferred, as it consumes available landfill capacity, and is not seen as deriving any value from the biosolids.

Incineration

Many of the larger municipalities in Ontario have used incineration for biosolids disposal or as a means of heat production for their treatment plants. In some cities, notably Toronto, biosolids incineration has faced significant public opposition and has not being politically acceptable since the late 1990's. However, neighboring cities continue to refurbish or expand incineration capacity. Most small cities of 100,000PE would not find incineration economically advantageous. Some small centres within a regional municipality may elect to work with larger nearby cities and haul dewatered or liquid biosolids to a larger facility for treatment and/or incineration. Biosolids could be incinerated alone, or in combination with municipal waste.

Use on arable land

The most common use for biosolids in Ontario is agricultural land application under a provincial Certificate of Approval. Most mid- to large-size wastewater treatment plants in Ontario were constructed with either aerobic or, more commonly, anaerobic sludge digestion. For the majority of small urban centers, biosolids are handled either as digested liquid biosolids, or as thickened sludge dredged from a treatment or storage lagoon. For an urban centre of 100,000PE, the distance to sufficient farm land would likely economically justify dewatering of the biosolids to minimize storage and transportation costs. The provincial guidelines contain stabilization and management practices for both liquid and solid biosolids and specific setbacks from water courses, wells, residences, groundwater, and bedrock. They also contain limits on metal in the biosolids, metals accumulation in soils, liquid and solids loading rates and nitrogen and phosphorus loading limits. Biosolids application during winter is not permitted in Ontario, so there is also a requirement for provision of 240 days of biosolids storage capacity.

Prior to obtaining a CofA for a field, and applying biosolids, an application must be submitted to the MOE that includes identification of the site, relevant setbacks, and current soil analysis results for metals. Once applied, a waiting period is required prior to harvest or animal grazing. Some of the standards for site restrictions and setbacks are provided in Table 2.

The benchmark biosolids could be applied under the Nutrient Management Act, at a rate designed to meet the nutrient requirements of the crop, up to 22 dry tonnes per hectare, with one such application allowed to a field every 5 years. The field would typically be used for the production of animal feed or crops such as corn, wheat, or soy. Use on fresh vegetable crops, or products in contact with the soil, is generally not allowed.

Table 2. Separation Distances and site restrictions

Feature	Distance (metres)	Notes
Water Table	0.3	Measured vertically
Drilled Wells more than 15 m deep	15	Measured horizontally
All other wells including dug wells	90	Measured horizontally
Municipal wells	100	Measured horizontally
Individual residences	90	Measured horizontally
Residential areas	450	Measured horizontally
Minimum Separation Distances of Spreading Sites from Watercourses *There must be a vegetated buffer strip between any biosolids application and any surface water.* *Minimum separation distance between biosolids application and surface water = 20m*		
Spreading Restrictions Related to Public Health and Pathogens		
Crop		
Hay and Haylage		3 weeks before harvest
Pasture for horses, beef or dairy cattle		2 months before grazing
Pasture for swine, sheep or goats		6 months before grazing
Commercial Sod		12 months before harvest
Small fruits		15 months before harvest
Tree Fruits and grapes		3 months before harvest
Vegetables		12 months before harvest

Fertilizer product

Very few places in Ontario currently produce and sell a biosolids fertilizer product that is regulated under the Federal Fertilizer**s** Act. The largest of these is currently the pelletizer facility in the City of Toronto, operated by Veolia Water Canada. Once fully operational, it should produce 25,000 dry tonnes per year of biosolids pellets for sale as fertilizer.

Forests

Some tests have been conducted in Ontario on the use of biosolids for silviculture. However, this is not a common option and would likely be limited to communities in the northern part of the province, closer to large reforestation areas.

Land reclamation

This option is currently not widely used in Ontario. Similar to forest use, this option is most applicable to the sparsely populated northern part of the province, where most mining activities take place. It has some limited potential in the more densely populated southern part of the province for closure of gravel pits and quarries.

By-products

This option is currently not used in Ontario and no specific regulation exists to govern the production or use of such products

Hauled wastes

Hauled wastes, from facilities not connected to wastewater treatment plants, are typically trucked to municipal wastewater treatment plants for treatment. Some wastes, such as residential septic tank wastes, have been directly applied to agricultural land, however, this practice is being phased out by new legislation requiring all such wastes to undergo treatment prior to land application.

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BACKGROUND

In 1985, expansion and upgrading of the Robert O. Pickard Environmental Centre commenced and by November 1992, the facility was fully operational. The Robert O. Pickard Environmental Centre is a Class IV Wastewater Treatment Facility. The following paragraphs summarize the key elements of each process.

Overview of the Robert O. Pickard Environmental Centre

Raw sewage pumping

Six pumps provide pumping with a maximum capacity of 1,278 MLD and a firm capacity of 852 MLD. Coarse screening is provided for the protection of the pumps and all air contacting the wastewater is processed to reduce odour emissions. Diesel generators provide power to a maximum of four raw sewage pumps (firm capacity of 852 MLD) in the event of a power failure.

Screening and degrit

Six bar screens are used for removal of solids with size greater than 14.5 mm. Aerated grit tanks are utilized for grit removal. All equipment, channels, and tanks are enclosed and the air contacting the wastewater is processed to reduce odour emissions.

Primary clarification

The primary clarification section has 15 rectangular clarifiers with flight and chain sludge/scum collection mechanisms. All tanks are covered to reduce odour emissions. Sludge is pumped from the clarifiers, using air diaphragm pumps, to an intermediate transfer station. High-rate pumps are then used to transfer the sludge to the anaerobic digesters.

The scum-handling process consists of the scum collection; scum concentrator and scum transfer station. The scum is collected into scum tanks by rotating slotted pipes below the water surface in the primary clarifiers to capture surface scum. The scum slurry is processed through grinders and pumped to a scum holding tank. The scum blanket is skimmed off the surface of the tank by a chain and flight mechanism that conveys scum to a concentrated scum tank that is heated to a minimum of 60°C. The concentrated scum is then pumped to the anaerobic digesters.

Secondary treatment

The Secondary Treatment Facility is arranged as a north plant and south plant. Each plant consists of four aeration tanks (fine bubble aeration), eight circular clarifiers and a return activated sludge/waste activated sludge pumping station. Phosphorous removal is achieved with the addition of ferrous chloride.

Solids handling – anaerobic digestion

Anaerobic digestion of raw sludge, thickened waste activated sludge and concentrated scum is carried out in four digesters, three of which are operated as high-rate mesophylic digesters. Digested sludge is gravity-fed from the three primary digesters into the fourth digester, which serves as a completely mixed centrifuge feed tank. All digested sludge is processed through the sludge dewatering facility (i.e., no supernatant decanting), thus maximizing solids capture. Digester gas is primarily burned in the Co-generation Facility and can also be burned in the East Boiler Plant as required. When neither the Co-generation Facility nor the East Boiler Plant is available, the gas is directed to a waste gas burner.

Co-generation facility

Digester gas is burned in three internal combustion engines each producing a maximum energy output of 810 kW electrical and 1,000 kW thermal. The equipment powered from sub-station #2 uses all electrical energy produced. Thermal energy is transferred to the plant hot water heating loop and is used for building and process heating. Excess thermal energy is wasted via the existing waste heat exchanger. The East Boiler Plant is used to provide additional heat as required.

Solids handling – thickening and dewatering

Waste activated sludge is thickened in centrifuges prior to being fed to anaerobic digesters. Digested sludge is dewatered, using centrifuges, to a solid content of 27% to 32%.

Effluent Disinfection

Final effluent disinfection is achieved with the addition of sodium hypochlorite. There are three contact tanks providing a contact volume of 10,850 m^3 and a contact time of 30 minutes at design average flow and 11 minutes at design peak flow.

Biosolids production

In 2006 the City of Ottawa generated 12,027 dry tonnes of biosolids. After dewatering the total solids concentration averaged 29.4%. Nutrients contained in the biosolids included 39,245 mg/kg of total phosphorus and 5,456 mg/kg of ammonia.

The following table compares the metal concentrations of the solids with the maximum acceptable metals concentration for land application in Ontario.

Metal	Concentration	Maximum acceptable
Arsenic	1 mg/kg	170 mg/kg
Cadmium	1 mg/kg	34 mg/kg
Cobalt	6 mg/kg	340 mg/kg
Chromium	50 mg/kg	2,800 mg/kg
Copper	460 mg/kg	1,700 mg/kg
Mercury	1 mg/kg	11 mg/kg
Nickel	16 mg/kg	420 mg/kg
Lead	51 mg/kg	1,100 mg/kg
Zinc	593 mg/kg	4,200 mg/kg

End use of biosolids

The following table outlines the end uses of the City of Ottawa's biosolids in 2006, in dry tonnes.

End uses	Total
Compost	7,560
Land Application	2,935
Landfill Cover	1,532

LAND APPLICATION

The City of Ottawa's biosolids program is administered using a biosolids management system that was developed using the key components of an environmental management system and quality management system. The land application of the City of Ottawa's biosolids is conducted using best management practises, developed under the direction of the Medical Officer of Health.

LANDFILL

Landfill disposal of the City of Ottawa's biosolids will only be used if current beneficial uses are not available.

INCINERATION

Incineration of biosolids in not currently practiced.

Québec

INTRODUCTION

Québec is the second largest and second most populated province of Canada. It covers an area of 1.7 million km^2. Its population of 7.7 million people is largely concentrated along the St-Lawrence River, close to the US border. The province has over 700 municipal wastewater treatment plants, which generate around 900 000 wet tons (or 230 000 dry tons) of sewage sludge annually (Perron & Hébert, 2007).

Québec has a *Residual Materials Management Policy 1998-2008,* which states that "The ultimate goal is to ensure that no sludge is landfilled until it has been demonstrated that recovery is not an economically viable option." (For more information, visit: *http://www.menv.gouv.qc.ca/matieres/mat_res-en/index.htm*). Accordingly, the Québec government encourages the beneficial use of sewage sludge.

In spite of the beneficial use policy, across the province approximately 35% of municipal biosolids are landfilled, 45% are incinerated, and only 20% are beneficially used as fertilizer or soil amendments. The relatively low rates of beneficial use for municipal sludges in Québec are mainly due to the low cost of landfilling and the presence of incinerators in the large cities.

For the purposes of this text, *sewage sludge* means an organic product obtained from the physico-chemical and/or biological treatment of wastewater; *biosolid* refers to a sewage sludge that meets the Québec criteria for beneficial use, and *fertilizing residual* means any residual materials intended for use in maintaining or improving plant nutrition and the physical and chemical properties and biological activity of soils, either separately or together that meets the Québec criteria for beneficial use. Fertilizing residuals include biosolids (MDDEP, 2004).

USE AND DISPOSAL PRACTICES OF SEWAGE SLUDGE/BIOSOLIDS

Landfill

Québec has a regulation respecting the landfilling and incineration of residuals. For more information, please see: *http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=3&file=/Q_2/Q2R6_02.htm*

In order to reduce the amount of material being sent to landfills and incinerators, a green tax of $10.41 (Canadian dollars) per ton is levied against all residuals that are landfilled.

For more information, please see: *http://www.mddep.gouv.qc.ca/matieres/redevance/index.htm*

Incineration

In Québec, 45% of municipal sludges are incinerated, with varying levels of heat recovery. This high percentage is due to the presence of incinerators in large cities (Montréal, Longueuil and Québec city). Ash is landfilled, except in Longueuil, where it is used for cement production. Laval, another large city, sends most of its pellets to a cement factory for fuel rather than beneficially using them in agriculture because of difficulties in obtaining good pellet size for agricultural use, and due to odours. (Hébert, 2004)

Land application/composting

Approximately 8 % of the municipal sludges generated in the province are directly land-applied on about 0.2% of Québec's agricultural land. Approximately 12% are composted and most of the resulting compost is used for non-agricultural purposes. Medium-sized towns account for the largest volumes of sludges beneficially used in agriculture. These include the towns of Gatineau, Sherbrooke, Saguenay, Victoriaville, Saint-Jean-sur-Richelieu and Drummondville. The sludges are used in a solid form and have been stabilized by such means as composting, pelletization, biological treatment or alkaline treatment (Hébert, 2007).

Some smaller municipalities beneficially use liquid sludges from lagoons and septic tanks. These sludges are generally dehydrated then sent to composting sites. However, on a dry-weight basis, the quantities remain limited, particularly for lagoons, which are generally emptied every 10 to 15 years (Hébert, 2004).

Regulating the use of land applied sewage sludge in Québec

A proponent, such as a municipality or specialized firm, wishing to land-apply biosolids must chose one of two approaches:

1. Certification by the Bureau de normalisation du Québec (BNQ). This option is mandatory for all municipal biosolids spread on food crops for human consumption.
2. Obtain a certificate of authorisation from the Ministère du Développement durable, de l'Environnement et des Parcs du Québec (MDDEP).

Bureau de normalisation du Québec Certification

The BNQ is a standards-development organization certified by the Standards Council of Canada and authorized to draw up commercial standards for fertilizing materials in Canada. BNQ standards are developed in keeping with International Organization for Standardization principles and methods. They are approved through a consensus-based approach involving manufacturers, consumers (users) and other stakeholders serving on a standards-writing committee. There are two BNQ standards regarding biosolids (composts and dried/alkaline municipal biosolids). Currently, only two biosolids products are certified by the BNQ as the certification process is labour-intensive and costly.

Certificate of authorisation

When biosolids are not certified by the BNQ, the proponent must apply for a certificate of authorization (CA) from the MDDEP. The regulatory requirements and beneficial use criteria that must be met before the ministry will issue a CA are detailed in the document "Guidelines for the beneficial use of fertilizing residuals", which are explained in more detail further in this text.

Compliance with federal regulation

Whether the residual is certified by the BNQ or has been issued a CA by the MDDEP, all fertilizers and supplements (soil amendments) sold or imported must comply with the federal labelling and safety standards detailed in the *Fertilizers Act* and the *Fertilizer Regulations*. The federal standards governing chemical contaminants and pathogens are very similar to the criteria applied by the MDDEP and BNQ, as they have the same origins. For more information visit: *http://www.inspection.gc.ca/english/plaveg/fereng/ferenge.shtml*

Québec Guidelines for the beneficial use of fertilizing residuals

The Guidelines cover all fertilizing residuals that are managed under a certificate of authorization.

As detailed in the Guidelines, municipal biosolids are classified according to their chemical contaminant content (C categories), pathogen content (P categories) and odour (O categories). This is called C-P-O classification. The classification has a major impact on site restrictions.

Chemical contaminants (C1 or C2 categories)

Maximum concentrations of chemical contaminants permitted in land-applied municipal biosolids are listed in Table 1.

The C1 criteria are based on the BNQ compost standards (BNQ, 2005) and the Canadian Council of Ministers of the Environment standards (CCME, 2005). The C2 criteria are based mainly on the B category criteria applied by the BNQ and the CCME for compost quality, which are essentially derived from the Canadian Food Inspection Agency criteria (CFIA, 1997)

Based on Québec's criteria, the benchmark sludge would be in the C2 category.

Table 1. Maximum limits for chemical contaminants in municipal sludges

	Maximum Limits (mg/kg, dry weight)	
Contaminants	**C1 Category[1]**	**C2 Category[1,2]**
Elements deemed essential or beneficial to plants or animals		
Arsenic (As)	13	40
Cobalt (Co)	34	150
Chromium (Cr)	210	1 060
Copper (Cu)	400	1 000[3]
Molybdenum (Mo)	5	20
Nickel (Ni)	62	180

Contaminants	Maximum Limits (mg/kg, dry weight)	
	C1 Category[1]	C2 Category[1,2]
Selenium (Se)	2.0	14
Zinc (Zn)	700	1 850
Other elements		
Cadmium (Cd)	3.0	10
Mercury (Hg)	0.8	4
Lead (Pb)	150	300
Dioxins and furans	17	50[4]

1. *For a fertilizing residual to qualify as C1, all parameters must meet the C1 criteria. For inclusion in the C2 category, all the parameters must meet the C2 criteria and at least one parameter must exceed the C1 criteria.*
2. *The loading limit for C2 residuals is 22 t (d.w.)/ha/5 years. However, with biosolids, loadings are generally first limited by nutrients*
3. *The maximum limit has been raised to 1 500 mg Cu/kg for residuals > 2.5 % P2O5, d.w., and for biosolids from municipal lagoons.*
4. *All elements: mg/kg, dry weight, except for dioxins and furans, which are expressed in ng TEQ/kg (d.w.) NATO toxic equivalents (TEQ) (NATO/CCMS, 1988). A fertilizing residual containing between 51 and 100 ng TEQ/kg of dioxins and furans can be used in non-agricultural applications.*

Pathogens (P1 or P2 categories)

Municipal biosolids must be virtually pathogen-free (P1) or partially disinfected (P2) before being land-applied; the criteria for pathogens are listed in Table 2. The criteria for municipal biosolids are mainly derived from the United States Environmental Protection Agency's class A and B criteria in combination with the pathogen and vector attraction reduction criteria (USEPA, 1993).

Table 2. Pathogen criteria for biosolids[1]

Category	Criteria
P1	a. Dried biosolids: ***Salmonella*** not detected in 10 g, **and** drying at a minimum temperature of 80°C, **and** dryness ≥ 92%. b. Composts: ***Salmonella*** not detected in 10 g **and** one of the following maturity criteria: • O_2 uptake rate ≤ 400 mg/kg organic matter/hour, **or** • CO_2 production ≤ 4mg C-CO_2/kg organic matter/day, **or** • Increase in temperature of < 8°C as compared to ambient temperature (self-heating test).
P2	a. Lime treatment: pH ≥ 12 for at least 2 hours **and** maintain at pH ≥ 11.5 for at least 22 hours. b. Biological treatment I: ***E. coli*** < 2 000 000 MPN[1, 2]/g (d.w.) **and** aerobic biological treatment **and** O_2 uptake rate of ≤ 1 500 mg O_2/kg organic matter/hour. c. Soil incorporation: ***E. coli*** < 2 000 000 MPN/g (d.w.) and incorporation of residual into soil in less than 6 hours. d. Biological treatment II: ***E. coli*** < 2 000 000 MPN/g (d.w.) **and** aerobic biological treatment **and** sludge age ≥ 20 days e. Lagoons***: E. coli*** < 2 000 000 MPN/g (d.w.) **and** biosolid from a lagoon not emptied since at least ≥ 4 years. f. Other treatments: ***Salmonella*** not detected in 10 g wet weight, for residuals with ≥ 15% dry matter (or in 50 g wet weight for other residuals) **and** O1 or O2 odour category.

1. *Alternatively, products/processes that meet the USEPA requirements for categories A or B are considered respectively to be P1 or P2 categories. However, the vector attraction reduction criteria must also be met.*
2. *MPN = most probable number*

Odours (O1, O2 or O3 categories)

Municipal biosolids are assigned an odour category according to their level of malodour (Table 3). The odour categories are based on results of an odour survey conducted among specialists familiar with fertilizing residuals and farm manures. For more information on the odour survey, see *http://www.mddep.gouv.qc.ca/matieres/mat_res/Article/article.htm*

Table 3. Odour criteria for municipal biosolids

Category	Definition	Examples
O1	Low odour: Odour less than solid dairy cattle manure.	Compost (mature)
O2	Malodorous: Odour similar to that of solid dairy cattle manure	Lagoons: from a lagoon not emptied since at least ≥ 4 years Limed biosolids Dried biosolids
O3	Strongly malodorous: Odour greater than solid dairy cattle manure, but less than hog slurry.	Biosolids from activated sludge treatment
Out of category	Odour greater than hog slurry	Biosolids from anaerobic digestors, further dehydrated using high speed centrifuges

Nutrient restrictions

Nitrogen and phosphorus are subject to regulatory restrictions when biosolids are applied on farm land. For each application site, a certified agronomist must draw up an agro-environmental reclamation plan that will limit nutrients based on crop needs.

The Regulation respecting agricultural operations also dictates setbacks to prevent contamination of surface waters. Finally, the Regulation respecting groundwater catchment also has mandatory setbacks to protect underground water supplies.

Crop restrictions

Biosolids certified by the BNQ may be used for any crops. Non-certified biosolids cannot be applied on pastures and on soils cultivated for human food crops, including home gardens. However, food crops may be sown on soils that received uncertified biosolids the year before, provided the time delay is respected for P2 category biosolids. The time delays are similar to those required by the USEPA (USEPA, 1993).

Other restrictions

There are other restrictions aimed at protecting the environment and human health, such as setbacks to protect air quality (bioaerosols and odours). The higher the C-P-O index, the tighter the restrictions will be. Accordingly, C1-P1-O1 category biosolids do not pose a significant risk with respect to chemical contaminants, pathogens or odours and therefore have minimal spreading constraints. On the other hand, there are many usage constraints for C2-P2-O3 category biosolids, as described in chapter 10 of the Guidelines.

A biosolids that does not meet the minimum C2-P2-O3 requirements is considered "out of category," and may not be used for agricultural or silvicultural purposes, except in special cases. However, these biosolids may be further processed to meet criteria.

Use in forests/woodland and for land reclamation

Municipal biosolids may be used for land reclamation, for example, the revegetation of degraded sites. They may also be applied as fertilizers in forests. Guidelines concerning the use of municipal biosolids on these sites were published by the Québec government in 2005: "Guide sur l'utilisation de matières résiduelles fertilisantes (MRF) pour la restauration de la couverture végétale de lieux dégradés" (MDDEP, 2005).

Septage

Criteria for the handling of septic tank sludge are essentially the same as those for municipal biosolids, and are detailed in the Fertilizing Residuals Guidelines. The sludge must meet the C-P-O criteria, and liquid septic tank sludge must be screened prior to land application.

ECONOMICS

The estimates are for the city of Montréal, which serves a population of 1.9 million people (Robin Forest, Ville de Montréal, personal communication). All amounts are in Canadian dollars.

Annual costs for waste water treatment plant (2004)

- Operations and maintenance: $52 million
- Sludge treatment and disposal: $22 million (42% of operations and maintenance costs)
- Financing (capital & interest), rough estimate: $54 million (90% paid by Quebec government and 10% by Montreal)

Charge to customers for treating one cubic metre of sewage in 2007

- Annual volume of wastewater treated (2007) = 927 million m^3
- Operations and maintenance costs (2007): $63 million
- Cost per m^3 (without financing): $0.068

Cost of diesel fuel (2007)

- $1.08/L for diesel used for trucks
- $0.85/L for diesel used for energy production

Cost of one kilowatt hour of electricity (2007)

- About $0.047/kWh before taxes

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Western Canada

INTRODUCTION – WASTEWATER MANAGEMENT IN WESTERN CANADA

Wastewater treatment and biosolids production is an issue of burgeoning importance in western Canada. The range of wastewater treatment processes is large due to smaller municipalities and regional districts existing alongside much larger population centres such as Metro Vancouver, Calgary, Edmonton, Regina, and Saskatoon. Overall, it is estimated that 19% of Canadians are served by primary treatment while 38% are served by secondary treatment, and that coastal communities are more likely to have primary or no treatment, while inland communities are more likely to have secondary or tertiary treatment (CCME, 2006).

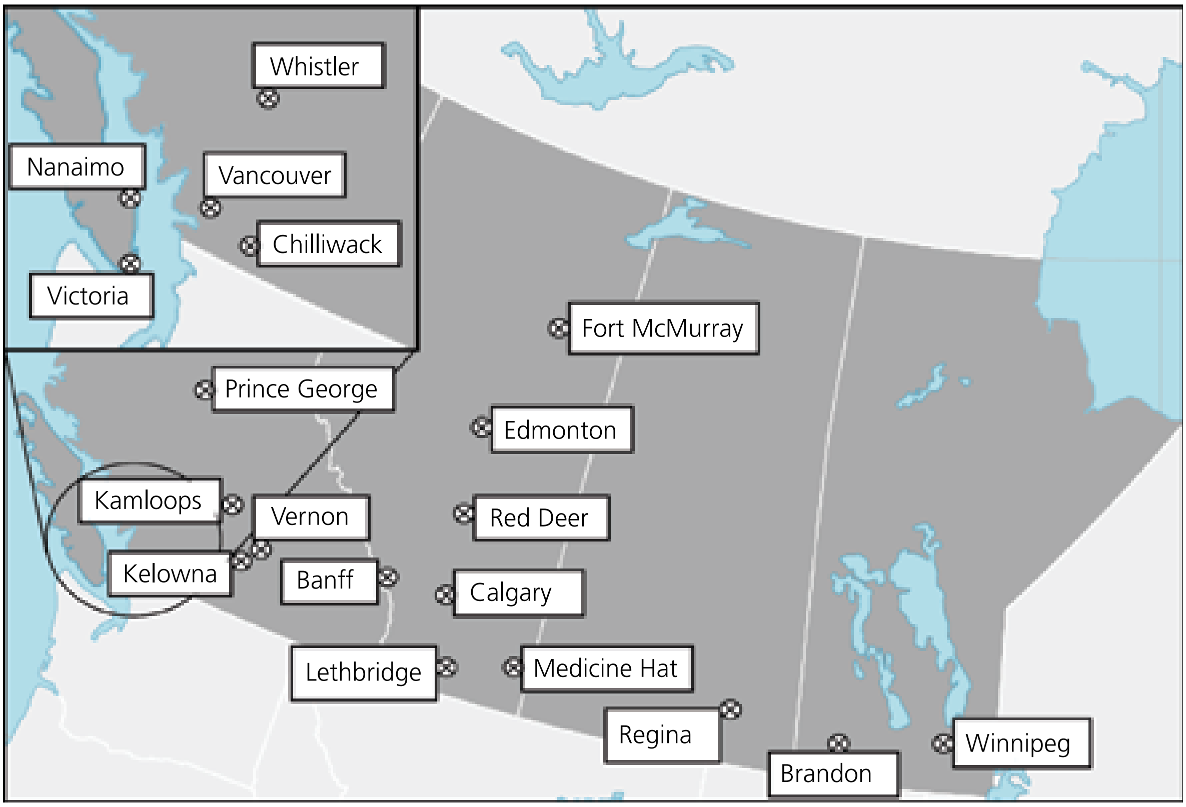
This submission for the second edition of the Global Atlas of Wastewater Sludge and Biosolids Use and Disposal, provides a review of biosolids management in western Canada. The submission summarizes wastewater treatment, biosolids production and quality; biosolids regulations and biosolids management options from several western Canadian jurisdictions. The submission also includes discussions on the management of the provided benchmark sludge under each regulatory scenario.

LOCATION AND METHODOLOGY

For the purposes of this submission, western Canada is comprised of the four westernmost provinces of Canada: British Columbia (BC), Alberta, Saskatchewan, and Manitoba. Together, these provinces have a population of approximately 10 million and a land area of 2.7 million square kilometres (km^2).

To collect the required information for the submission, a short survey was developed and distributed to 22 jurisdictions within the study area. A total of 19 jurisdictions completed the survey. These 19 jurisdictions have a total population of five million (51% of the total population of western Canada), and are serviced by 25 wastewater treatment plants (WWTPs) which produced 97,525 dry tonnes (dt) of treated biosolids in 2007. Figure 1 provides a map of the study area and the jurisdictions surveyed.

Figure 1. Map of western Canada and surveyed jurisdictions



REGULATORY FRAMEWORKS

Wastewater treatment

Nationally, wastewater treatment is partially regulated by the *Canadian Environmental Protection Act*, which specifies concentration limits of ammonia and chlorine in wastewater effluents. The *Fisheries Act* regulates parameters such as biological oxygen demand, total suspended solids, pH, and electrical conductivity to protect aquatic habitat in effluent-receiving waters. Provincially, wastewater effluent is subject to other regulations governing maximum allowable limits for additional constituents (see Table 1).

Table 1. Provincial regulations governing treatment of wastewater effluent

Province	Name of Regulation
BC	Municipal Sewage Regulation
Alberta	Environmental Protection and Enhancement Act
	Activities Designation Regulation
	Wastewater and Storm Drainage Regulation
Saskatchewan	The Water Regulations, 2002
Manitoba	The Environment Act
	Water Works, Sewerage and Sewage Disposal Regulation

Biosolids management

At the national level, the production and management of biosolids is currently unregulated in Canada, although the Canadian Council of Ministers of the Environment (CCME) is planning to address biosolids in conjunction with a municipal wastewater effluent management strategy. Rather, biosolids quality and management are regulated by the provinces. Some provinces have developed their own regulations or guidelines, while others refer to the well-established United States Environmental Protection Agency (USEPA) Part 503 Rule. Applicable regulations for the four western provinces are listed in Table 2.

Table 2. Provincial regulations governing the use and disposal of biosolids

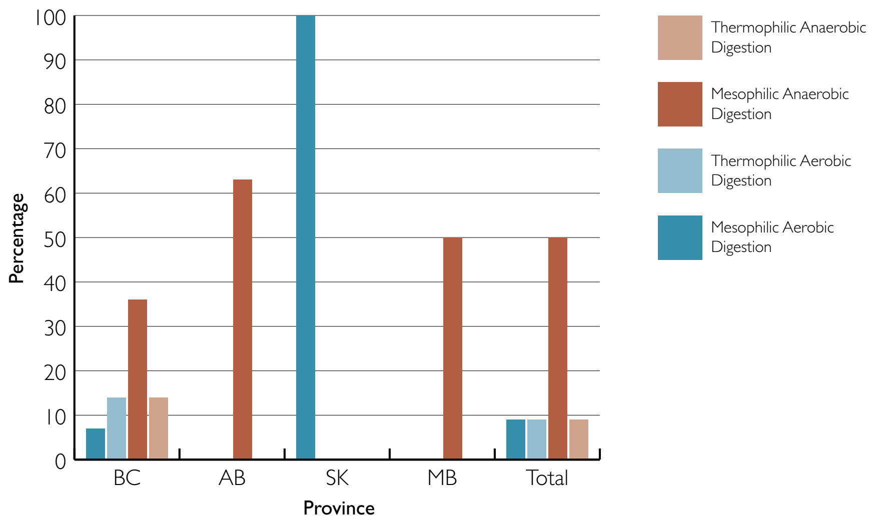
Province	Regulation
BC	Organic Matter Recycling Regulation
Alberta	Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands
Saskatchewan	Land Application of Municipal Sewage Sludge Guidelines
Manitoba	Environment Act (License-based)

WASTEWATER TREATMENT TECHNOLOGIES

Canada has various factors influencing policy concerning the quality of discharged effluent and biosolids. The overall density of population is very low (3.7 people/km^2). Consequently, the receiving environment is large in comparison to the total amount of waste produced. Western Canada also has coastal communities that can take advantage of the ocean and the circulating actions of tides and currents to remove wastewater from the local environment. Because of these factors, coastal and remote communities are more likely to have more rudimentary wastewater treatment systems. Conversely, a high percentage (67%) of western Canada's population is urbanized, living in cities with populations over 50,000. Such densities contribute both to increased production of wastewater as well as to the development of advanced wastewater treatment systems and biosolids management strategies.

Figure 2 shows the distribution of treatment type by surveyed jurisdictions. The data for Saskatchewan represents a single survey respondent only. Mesophilic and thermophilic refer to the optimal temperature ranges that support the growth of microorganisms required for these digestion processes. The optimal temperature ranges for mesophilic and thermophilic digestion are 25 – 40°C and 55 – 65°C respectively.

Figure 2. Biosolids treatment by province in western Canada



BIOSOLIDS MANAGEMENT OPTIONS IN WESTERN CANADA

Over the last few decades, biosolids disposal as a management option has been decreasing, while beneficial re-use options have been developed and are increasing. The following management options represent those most commonly implemented in western Canadian biosolids management programs.

Land application

Biosolids can be applied to agricultural or marginal land to improve the soil structure and nutrient status. Biosolids are typically applied by manure spreader (Photograph 1) and incorporated with agricultural discs, injected directly into the soil, or applied and then covered to mitigate odour generation and reduce vector attraction. Depending on biosolids quality, grazing and harvesting restrictions can be imposed following agricultural applications to allow a period of attenuation of the biosolids to the existing plant/soil systems. An agronomic biosolids application rate supplies the nutrients required by the planned cropping system, reducing the possibility of off-site movement of constituents, which can contaminate watercourses.

Biosolids' value as a fertilizer enables their use as a fertilizer for forest stands. Applications are made at an agronomic rate. Application technologies range from applying slurry or re-watered biosolids from a hose or cannon to the spreading of dewatered biosolids from a vehicle mounted with a side-discharge fan applicator (Photograph 2). Typical objectives in biosolids forest fertilization activities include accelerated tree growth, improved wildlife habitat, rapid green-up and improved visual quality, and erosion mitigation following forest fires or natural disturbances.

Photograph 1: Biosolids application to agricultural land. Photo © SYLVIS Environmental

Photograph 2: A side-discharge fan applicator for forest application of biosolids. Photo © SYLVIS Environmental

Land reclamation

Biosolids are useful as a soil conditioner or fertilizer on degraded sites where the original soil has been removed and organic matter has been lost through respiration or erosion, such as mines, sedimentation ponds, roads, or gravel pits. Incorporation of biosolids increases soil organic matter and provides a microbial inoculant and a source of macro- and micronutrients essential to the establishment and maintenance of vegetation.

Product Development: Composting and Soil Fabrication

Biosolids can be used as a feedstock and co-composted with other materials such as wood waste or municipal solid waste to produce high-quality products that can be marketed for residential and commercial use. For example, the City of Kelowna, BC, has two such marketable products: Nature's Gold® and Ogogrow®. Composts are utilized primarily for their soil amending properties. The addition of compost to disturbed soils improves the soil physical characteristics, including water holding capacity, bulk density and aggregation. Improvements in physical characteristics leads to increased movement of air, water and nutrients throughout the soil profile, facilitating vegetation establishment.

An innovative use of biosolids is as a feedstock in soil fabrication. When mixed with a carbon feedstock such as wood and a mineral feedstock such as sand, nitrogen-rich biosolids can help form a productive soil medium (Photograph 3). Under BC's *Organic Matter Recycling Regulation* (OMRR) (BC Ministry of Environment, 2002), Class A or Class B biosolids meeting Class A pathogen and vector attraction reduction standards can be used to produce a fabricated growing medium that can be distributed and used without restriction.

Photograph 3: Soil fabrication using biosolids. Photo © SYLVIS Environmental

Incineration

Incineration with or without energy recovery of sewage sludge and biosolids is an effective method of biosolids disposal. Upon drying, biosolids can be used as a fuel in cogeneration and industrial activities. Currently there are no biosolids incineration/waste-to-energy facilities operating in the surveyed jurisdictions. The development of new and cleaner waste-to-energy technologies may generate renewed interest in this option in the future.

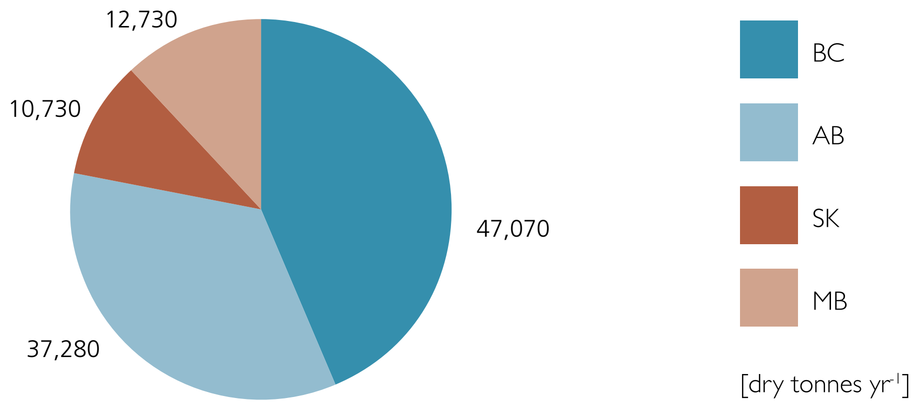
Landfilling

Landfilling of biosolids is still occurring in some jurisdictions, but represents a minority share of total biosolids management. Difficulty in securing new landfill sites, logistics in handling, and initiatives to remove organics from landfilling minimizes biosolids disposal in landfills. Consequently, many larger jurisdictions have banned biosolids disposal in landfills. More recently, biosolids have been used as components in topsoils for landfill closure systems to facilitate the establishment of vegetation as well as in engineered biocover systems that can effectively mitigate fugitive landfill methane emissions. This represents a shift in that biosolids are utilized beneficially *on* landfills rather than disposed of *in* them.

BIOSOLIDS PRODUCTION AND MANAGEMENT TRENDS IN WESTERN CANADA

In the absence of accurate data on total biosolids production for each province, an estimate was made based on an average per capita production of 27.7 kg (dry weight) of biosolids per year multiplied by the population with access to WWTPs with at least secondary treatment (see Figure 3).

Figure 3. Annual biosolids production (dry tonnes) by province in Western Canada



As summarized in Table 3 below, the most common management option, engaging 32% of respondents and 45% of 2007 biosolids production, was agricultural land application. The short-term (i.e., five-year) outlook for this management option appears to be positive, as more than a quarter of the jurisdictions intend to increase or maintain current agricultural land applications of biosolids.

Composting was the second most prevalent biosolids management option, accounting for 27% of biosolids production and implemented in 32% of the surveyed jurisdictions. This practice is anticipated to increase in the short term within the surveyed jurisdictions (28% of respondents will increase or not change their use of this option). Forty percent of the jurisdictions reported composting was a locally available management option, and 24% produced a marketable biosolids compost product.

Land reclamation accounted for 20% of the total biosolids recycled and was utilized by 32% of the surveyed jurisdictions. Only 16% of the surveyed jurisdictions cited this as a local management option; however, the use of biosolids in land reclamation is likely to become more common with 36% of the surveyed jurisdictions forecasting an increase or continuation of current practices in their use of this option.

More marginal options such as ranch fertilization (3%), application to forest land (1%), and soil product development (<1%) accounted for most of the remainder of total production, but the latter two options show signs of growth over the next five years.

A total of 4% of biosolids in western Canada are being disposed of in landfills, and 20% of these cases involve local projects. Although more than a quarter of respondents reported using this management option, 21% forecast a decrease. Typically, disposal of biosolids in landfills represents a management option for biosolids that do not meet regulatory requirements for land application. Conversely, incineration, which is presently not practiced, may become a more common option with a fifth of respondents interested in diversifying their program with this option.

Table 3. Biosolids use and disposal trends in western Canada

Option	% of Total Production	% of Respondents	Local Option	Marketable Product	Forecast
Application to agricultural land	45%	32%	44%	12%	28% to increase or not change, 16% to decrease
Application to forest land	1%	8%	12%	8%	16% to increase or not change
Use in land reclamation	20%	32%	16%	8%	36% to increase or not change
Composting	27%	32%	40%	24%	28% to increase or not change
Development of soil products	0%	20%	36%	36%	36% to increase
Ranch fertilization	3%	20%	0%	0%	20% to not change
Energy recovery	0%	0%	4%	4%	4% to increase
Gasification	0%	0%	4%	4%	4% to increase
Disposal to landfill	4%	28%	20%	0%	4% to not change, 21% to decrease
Incineration	0%	0%	20%	0%	20% to increase

BRITISH COLUMBIA

British Columbia has a population of 4.3 million and a land area of 925,000 km^2. The climate of BC is varied, with annual average temperatures ranging from -0.8 to 10.1°C, average July daily highs of 16.1 to 28.3°C, average January lows of -25.6 to 0.5°C, and an annual average rainfall of 270 to 2,500 mm per year.

Regulatory review

Enabling regulations and the use of qualified professionals has resulted in a shift away from a system of ongoing permits and one-time approvals to a regulatory framework designed to encourage beneficial re-use of biosolids. The OMRR regulates the management and utilization of biosolids generated in BC. Promulgated in 2002, the OMRR replaced the *Production and Use of Compost Regulation* and includes regulations for both biosolids and compost. Biosolids that can be land-applied under the OMRR are designated either Class A or Class B biosolids. Biosolids meeting Class A or Class B standards are subject to different quality and process criteria including:

- pathogen reduction processes;
- vector attraction reduction;
- pathogen reduction limits;
- quality criteria, including trace elements limits;
- sampling and analysis protocol and frequency; and
- record-keeping.

Table 4 presents a summary of compliance quality criteria for trace elements and fecal coliform concentrations for Class A and B biosolids quality in BC. As a potentially marketable product, Class A biosolids are categorized as a fertilizer. As such, the limits presented in the OMRR are adopted from the *Federal Fertilizers Act* (FFA). The FFA and the *Fertilizer Regulations* set standards for all biosolids and biosolids products marketed in Canada. The OMRR requires Class A biosolids to meet standards specified in *Trade Memorandum T-4-93 (September 1997) Standards for Metals in Fertilizers and Supplements*. Changes adopted by Agriculture and Agri-Food Canada under the fertilizer regulations can therefore impact biosolids quality regulated by the OMRR. The Class A and Class B limits differ slightly; chromium and copper are not regulated under the FFA and thus do not appear in Class A limits. Additionally, the Class A mercury and fecal coliform limits are more stringent than the Class B limits.

Table 4. Quality-based biosolids criteria under OMRR

Constituent	Class A Limits	Class B Limits	Units
Trace Element			
Arsenic	75	75	mg/kg
Cadmium	20	20	mg/kg
Chromium	-	1,060	mg/kg
Cobalt	150	150	mg/kg
Copper	-	2,200	mg/kg
Lead	500	500	mg/kg
Mercury	5	15	mg/kg
Molybdenum	20	20	mg/kg
Nickel	180	180	mg/kg
Selenium	14	14	mg/kg
Zinc	1,850	1,850	mg/kg
Microbiological			
Fecal Coliform	< 1,000	< 2,000,000	MPN/g[1]

[1] *Most probable number per gram.*

Each class of biosolids is also subject to specific land application and distribution requirements including:

- volume restrictions;
- requirements for approval of use through a land application plan (LAP);
- post-application soil standards provided in the OMRR or site-specific standards approved by regulators; and
- if required, site access restrictions, buffer requirements, and biosolids incorporation requirements.

Post-application soil quality monitoring is generally required following biosolids applications. Matrices for eleven trace elements, adapted from the *BC Contaminated Sites Regulation*, stipulate post-application soil concentrations. These values are dependent on intended land uses and site-specific factors including expected exposure pathways.

A LAP is generated and submitted to regulators prior to any application of Class A biosolids exceeding 5 m^3 and Class B biosolids. The LAP outlines:

- the objectives and duration of biosolids use;
- site characteristics including location and access, geography, geology, hydrology and current land uses;
- delineation of biosolids application areas;
- biosolids characterization, including nutrient and trace element concentrations, and a description of the processes used to achieve the indicated biosolids quality;
- projection of post-application soil quality; and
- on-site management considerations to ensure environmental protection.

Accompanying the LAP are letters authorizing an agent to conduct activities related to biosolids management and application, and, from the landowners, authorizing the use of biosolids on their land.

The promulgation of the OMRR replaced the previous permitting and approvals system for biosolids recycling in British Columbia. In 1983, the Ministry of Water, Land and Air Protection produced the *Guidelines for the Disposal of Domestic Sludge under the Waste Management Act*. This "draft" guideline was provided to Regional Waste Managers to use in allowing municipalities to clean out biosolids storage lagoons by using the biosolids as a fertilizer on agricultural land. The guideline stipulated biosolids quality, cumulative soil trace element limits, and agricultural application rates.

Under this guideline and the former regulatory framework, biosolids could be land-applied in BC under a permit or approval. Permits allow for annual applications of biosolids to a site, with maximum limits established for dry solids, nitrogen, and other parameters depending upon biosolids quality and site-specific environmental conditions. Environmental monitoring and reporting were also prescribed on a site-by-site basis. A permit application required a proactive stakeholder review. The Ministry of Environment Regional Manager had broad discretionary powers in determining the extent of the stakeholder participation required. Stakeholder consultation activities included posting of signs at the biosolids application site, notification in the BC Gazette and one or more local papers, door-to-door notification of neighbours, public meetings, and a much broader permit review by other government agencies. An approval was typically issued for one-time applications of biosolids during a restricted time period of up to 15 months. Approvals did not usually require stakeholder review as did permits, and were often issued more quickly than permits.

While OMRR was implemented to eliminate the need for permitting or approval, there exist special cases where permits and approvals are used. If the land application of biosolids that do not meet minimum (i.e., Class B) quality and process criteria is desired, their use must be controlled by permit. Similarly, if soil trace element concentrations exceed the post-application limits before biosolids have been applied, then a permit is required. This is the case in many mine reclamation programs where the native or redistributed soils often contain elevated levels of trace elements.

Biosolids production and quality

A total of 14 WWTPs were surveyed in BC, representing 48.4% of the provincial population. As the survey targeted municipalities with populations over 50,000, the proportion of the population excluded from the study is less likely to have WWTPs capable of producing large amounts of biosolids. The 14 WWTPs surveyed produced a total of 31,265 dry tonnes (t_{dw}) in 2007 from a total wastewater flow of 1,457 million litres per day (MLD). Overall, the most common form of sludge treatment is mesophilic anaerobic digestion (36%), although in BC treatment by thermophilic anaerobic digestion (14%), thermophilic aerobic digestion (14%), and mesophilic aerobic digestion (7%) is also practiced.

Average trace element concentrations for BC biosolids were within the Class A and B limits set out in the OMRR, and are summarized in Table 5. Applicable benchmark sludge data are also presented for the purpose of comparison.

Table 5. Average trace element concentrations and provincial regulatory limits in British Columbia

Trace Element	Average BC Biosolids Concentrations (mg/kg)	Benchmark Sludge (mg/kg)	Regulatory Limit – OMRR Class A (mg/kg)	Regulatory Limit – OMRR Class B (mg/kg)
Arsenic	4.6	-	75	75
Cadmium	2.3	3	20	20
Chromium	50.7	-	-	1,060
Cobalt	5.2	-	150	150
Copper	888	500	-	2,200
Lead	56	200	500	500
Mercury	3.1	3	5	15
Molybdenum	7.6	-	20	20
Nickel	26.4	-	180	180
Selenium	4.2	-	14	14
Zinc	588	1,000	1,850	1,850

Biosolids management options

Biosolids use in reclamation was the most common management option at 62% of 2007 production, followed by composting (24%), ranch fertilization (8%), application to agricultural land (3%), application to forest land (2%), and development of soil products (1%). An additional 1% was disposed of in landfills. Land reclamation was not a local or marketable option for any respondent, while 29% reported local and marketable options for composting, and 43% for soil product development. The most significant five-year forecast was for an increase in development of soil products (43% of respondents). The same 36% that reported disposal in landfills also forecast a decrease of this option in favour of incineration, which is currently not practiced. A summary of biosolids management options in BC is provided in Table 6.

Table 6. Current biosolids management trends and five-year forecast in British Columbia

Option	% of Production	% of Respondents	Five-year Forecast
Application to agricultural land	3%	8%	14% to increase or not change
Application to forest land	2%	14%	14% to increase or not change
Use in land reclamation	62%	57%	43% to not change
Composting	24%	29%	14% to not change
Development of soil products	1%	36%	43% to increase
Ranch fertilization	8%	36%	36% to not change
Disposal to landfill	1%	43%	36% to decrease
Incineration	0%	0%	36% to increase

Management of the benchmark sludge

The benchmark sludge meets the most stringent biosolids quality criteria under the OMRR and any biosolids derived from it, provided they meet with pathogen and vector attraction reduction process criteria, and would be classified as Class A (see Table 5). In quantities less than 5 m³, they could be applied without a LAP or distributed for retail purposes. Subject to additional quality criteria, they could be incorporated into a biosolids growing medium or composted and marketed to the public without restrictions. In quantities greater than 5 m³, the land application rate would be limited by nitrogen content rather than trace elements. While the maximum agronomic rate will depend on site, crop, desired yield, and climate, rate estimates for three potential application scenarios are presented in Table 7. These application rates assume the benchmark total nitrogen concentration of 3.5% is composed of primarily organic nitrogen with negligible contributions of ammonium and nitrate nitrogen.

Table 7. Agronomic application rate of the benchmark sludge in three cropping systems in British Columbia

Cropping System	Tree/Crop Uptake (kg N/ha/yr)	Understory Uptake (kg N/ha/yr)	Agronomic Application Rate (dt/ha)
Hybrid poplar at canopy closure (short rotation); understory: grasses and herbaceous	300	150	84
Douglas-fir at canopy closure; understory: *Gaultheria spp., Mahonia spp.*	125	50	40
Grass-legume mix stands for hay or silage production; coastal and southern interior of BC; high (normal) fertility site; 10 t/ha yield	260	0	54

Strictly from a trace element perspective and based on the benchmark soil, the maximum allowable application rate is 198 dt/ha and is limited by the zinc concentration, specifically when considering the exposure of aquatic life to surface water contaminated by groundwater flow when the soil pH is less than 6 (see Table 8).

Table 8. Maximum land application rate based on trace element limits (British Columbia)

Trace Element	Concentration in Biosolids (mg/kg)	Pre-application Soil Concentration (mg/kg)	Estimated Post-application Soil Concentration (kg/ha)	Provincial Limit (kg/ha)	Determining Factor
Cadmium	3	0.10	0.8	2.7	Groundwater used for drinking water, pH <6.5
Copper	500	10	117	162	Groundwater flow to surface water used by aquatic life, pH <5
Lead	200	20	75.6	180	Groundwater used for drinking water
Mercury	3	0.05	0.7	1.08	Livestock ingesting soil and fodder
Nickel	40	15	34.9	270	For all factors
Zinc	1,000	40	270	270	Groundwater flow to surface water used by freshwater aquatic life, pH<6

Application rate: 198 dt/ha
Soil bulk density: 1,200 kg/m³
Soil depth: 0.15 m

Economic indicators

Economic indicators and biosolids treatment and management costs as a proportion of capital, operating and maintenance costs were averaged for the province and are summarized in Table 9.

Table 9. 2007 average economic indicators and treatment and management costs in British Columbia (Canadian dollars)

Cost Per Customer to Treat 1 m^3 of Wastewater	Cost of 1,000 L Diesel	Cost of 1 kwh of Electricity	% of Annual Sewage Treatment Costs Attributed to Biosolids	
			Capital (%)	O & M[1] (%)
$0.32	$957.75	$0.05	30%	30%

[1] *Operations and maintenance costs.*

ALBERTA

Alberta has a population of 3.4 million and a land base of 642,000 km². Northern Alberta is generally comprised of boreal forest, while southern Alberta is primarily a semi-arid climate. Alberta has cold winters, with temperatures averaging -8°C in the south to -24°C in the north. Average temperatures in the summer range from 16°C in the Rocky Mountain and northern regions to near 30°C in the drier prairie regions. The average annual precipitation province-wide ranges from 300 to 600 mm.

Regulatory review

In Alberta, biosolids quality and management is governed by the *Guidelines for the Application of Municipal Sludges to Agricultural Lands* (hereafter referred to as "the Alberta Guidelines"), authorized under the *Alberta Environmental Protection and Enhancement Act*. The Alberta Guidelines emphasize that "application of sludge to land for treatment must be agriculturally beneficial and environmentally acceptable" (Alberta Environment, 1996). These guidelines apply only to application of biosolids to agricultural land; applications to marginal or disturbed lands are still assessed and permitted on a site-specific basis. A pre-application study is required to identify the following:

- constituents limiting land application in the biosolids itself;
- site and soil characteristics which may limit application and treatability of the waste; and
- information concerning application rates, timing, and management and siting requirements for use in designing a land treatment program.

Rather than gravimetric limits, the Alberta Guidelines stipulate minimum biosolids constituent ratios of trace elements to macronutrients (especially nitrogen and phosphorus). The intention of this approach is to "discriminate against biosolids with high metals but low nutrients" (Alberta Environment, 1996). The Alberta Guidelines recommend that biosolids quality can be improved by lowering trace element inputs or by improving handling and storage, which can conserve nutrients while forbidding any addition of nitrogen or phosphorus to meet requirements.

Table 10 lists site and soil characteristics used to assess land application opportunities. Low pH, steep slopes, certain soil textures, and proximity to potable aquifers can affect the suitability of a site for application.

Table 10. Site and soil characteristics limiting land application of biosolids

	Acceptable			Unacceptable
Factor	**Class 1 Sites**	**Class 2 Sites**	**Class 3 Sites**	**Class 4 Sites**
pH	>6.5	>6.5	>6.5	<6.5
Texture[1]	CL, SiCl, SiL, Si, SiC, L, SCL, SC	C, HC	LS, SL	Sand and gravel
Slope (%)	0-2	2-5	5-9	>9
Depth to potable aquifer (m)	>5	3-5	2-3	<2

[1] *Abbreviations are for soil texture identification based on the Canadian soil texture triangle.*

The Alberta Guidelines provide criteria for the development of a biosolids application program, sampling and analytical methodology, equipment calibration, and application of biosolids. The biosolids application program includes three main components:

- biosolids characterization: sampling and analysis;
- site and soil characterization: site properties, soil sampling and analysis (pH, particle size distribution, plant available nitrogen and phosphorus, and lime requirements); and,
- land treatment program design: biosolids classification and quality criteria, site and soil classification criteria, biosolids application rate criteria, and additional application restrictions.

Total number and depth of soil samples are specified, as well as pertinent soil properties and suggested analytical methods. A maximum annual application rate of 25 t_{dw}/ha/yr is allowed, and application methods are limited to injection (preferred) or surface application. There are also various restrictions on land use following application, including minimum waiting periods to harvest crops and pasture cattle.

Other types of biosolids management options, such as soil fabrication and forest application, are not covered by these Guidelines and are governed by permits issued by Alberta Environment.

Biosolids production and quality

A total of eight WWTPs were surveyed in Alberta, representing 60% of the provincial population. The eight WWTPs surveyed produced a total 50,900 t_{dw} in 2007 from a total wastewater flow of 856 MLD. Preference for mesophilic anaerobic digestion of sludge was unanimous for those plants which produced biosolids.

Average nitrogen-to-trace element ratios for AB biosolids were above the minimum acceptable ratios outlined in the Alberta Guidelines, as summarized in Table 11. Applicable benchmark sludge data are also presented for the purpose of comparison.

Table 11. Average nitrogen: trace element ratios and provincial regulatory limits in Alberta

Trace Element	Average Alberta Biosolids Concentrations (mg/kg)	Average Nitrogen:Trace Element Ratio[1]	Nitrogen:Trace Element Ratio of Benchmark Sludge	Regulatory Ratio-based Limit
Cadmium	2.5	23,200	11,667	1,500
Chromium	337	172	-	20
Copper	398	146	70	15
Lead	56	1,036	175	20
Mercury	1.1	52,727	11,667	3,000
Nickel	109	532	875	100
Zinc	571	102	35	10

[1] Average total nitrogen concentration for surveyed jurisdictions was 5.8% (58,000 mg/kg).

Biosolids management options

Application of biosolids to agricultural land was the most popular management option with 63% of respondents using 65% of total provincial biosolids production. The remainder was composted to produce material which was largely used for landfill cover or land reclamation. Agricultural application was forecast to decrease in favour of new alternatives, all of which were not currently being practiced (see Table 12).

Table 12. Current biosolids management trends and five-year forecast in Alberta

Option	% of Biosolids Production	% of Respondents	Forecast
Application to agricultural land	65%	63%	25% to increase
			25% to not change
			38% to decrease
Application to forest land	0%	0%	26% to increase or not change
Use in land reclamation	0%	0%	38% to increase or not change
Composting	35%	38%	51% to increase or not change
Development of soil products	0%	0%	38% to increase
Energy recovery	0%	0%	13% to increase
Gasification	0%	0%	13% to increase

Management of the benchmark sludge

While the maximum agronomic application rate will depend on site, crop, desired yield, and climate, rate estimates for two potential application situations are presented in Table 13. These application rate calculations assume that the benchmark total nitrogen concentration of 3.5% is composed of primarily organic nitrogen with negligible contributions of ammonium and nitrate nitrogen.

Table 13. Agronomic application rate of the benchmark sludge in two cropping systems in Alberta

	Crop Uptake (kg N/ha/yr)[1]	Agronomic Application Rate (dt/ha)
Wheat	94[1]	28
Canola	107[1]	30

[1] N demand adopted from AARD, 2008[a], yields adopted from AARD, 2008[b].

Nitrogen-to-trace element ratios in the benchmark sludge are greater than the ratio limits stipulated by the Alberta Guidelines, and thus meet the requirements for land application. Using the benchmark sludge and soil concentrations, an application of 22 dt/ha of the benchmark sludge to agricultural land could be made in compliance with cumulative trace element addition limits (Table 14). Trace element additions in a single application must not exceed one-third of the cumulative addition limits specified in Table 14. Thus, following the data presented in Table 14, the application rate of the benchmark sludge to a Class 3 site is limited by mercury, as the addition of 0.06 kg/ha of mercury is approaching one-third of the Class 3 cumulative additions limit of 0.2 kg/ha. Other uses, such as forest fertilization, land reclamation, composting, incineration, or landfilling would require a permit issued by Alberta Environment.

Table 14. Maximum benchmark sludge land application rate based on trace element limits in Alberta

Trace Element	Concentration in Biosolids (mg/kg)	Pre-application Soil Concentration (mg/kg)	Addition to Soil (kg/ha)	Allowable Cumulative Addition Limits (kg/ha)		
				Class 1 Site	Class 2 Site	Class 3 Site
Cadmium	3	0.10	0.1	1.5	1.1	0.8
Copper	500	10	10.5	200	150	100
Lead	200	20	4.2	100	75	50
Mercury	3	0.05	0.06	0.5	0.4	0.2
Nickel	40	15	0.8	25	19	12
Zinc	1,000	40	21.0	300	200	150

Application rate: 22 dt/ha
Soil bulk density: 1,200 kg/m^3
Soil depth: 0.15 m

Economic indicators

Economic indicators and biosolids treatment and management costs as a proportion of capital, operating and maintenance costs were averaged for the province and are summarized in Table 15.

Table 15. 2007 average economic indicators and treatment and management costs in Alberta (Canadian dollars)

Cost per Customer to Treat 1 m^3 of Wastewater	Cost of 1,000 L Diesel	Cost of 1 kwh of Electricity	% of Annual Sewage Treatment Costs Attributed to Biosolids	
			Capital (%)	O & M[1] (%)
$0.41	$1,008.19	$0.07	16%	20%

[1] Operations and maintenance costs.

SASKATCHEWAN

Saskatchewan has a population of nearly one million and a land base of 592,000 km^2. Like Alberta, Saskatchewan consists primarily of boreal forest to the north, and prairies to the south. Annual mean temperatures across the province range from -4 to 4°C. Average January temperatures range between -24 to -13°C and July average temperatures range between 15 and 19°C. Annual precipitation ranges from 300 to 430 mm.

Regulatory review

Land application of biosolids is governed by the Land Application of Municipal Sewage Sludge Guidelines (hereafter referred to as "the Saskatchewan Guidelines"), issued by the Environmental Protection Branch of the Saskatchewan Ministry of Environment (SE). A permit from SE is required to construct, extend or alter a municipal sewage sludge application. This permit is ostensibly for the operation of sewage works and includes an approval to land-apply biosolids. An application for a permit must include information on:

- a legal description of the land;
- analyses of the municipal sludge with comparisons to specified criteria;
- details of sludge stabilization;
- physicochemical analyses of receiving soil;
- data on water table locations, and flow and usage of underground aquifers;
- copy of land control agreements;
- contingency plans; and,
- results of hydrogeological investigation, if deemed necessary.

The permit also outlines requirements for sludge treatment, including water reduction and stabilization, and application site restrictions. Maximum acceptable concentrations of trace elements in biosolids as well as in post-application soil are also listed (see Table 16).

Table 16. Maximum acceptable concentrations of metals in biosolids and soil in Saskatchewan

Trace Element	Biosolids Limit (mg/kg)	Soils (mg/kg)		
		Agricultural Land	Commercial Land	Industrial Land
Arsenic	75	12	12	12
Cadmium	20	1.4	22	22
Chromium	1,060	64	87	87
Cobalt	150	40	300	300
Copper	760	63	91	91
Mercury	5	6.6	24	50
Molybdenum	20	5	40	40
Nickel	180	50	50	50
Lead	500	70	260	600
Selenium	14	1	3.9	3.9
Zinc	1,850	200	360	360

Pre-application biosolids is sampled as per the approved methods of the US Environmental Protection Agency (USEPA) and *Standard Methods for the Examination of Water and Wastewater*. The soil at the application site must be sampled every two years, and records relating to application rate, materials quality analyses, and crop types and yields must also be submitted to Saskatchewan Environment every two years.

Biosolids production and quality

One WWTP was surveyed in Saskatchewan, representing 19% of the provincial population. The WWTP surveyed produced a total 1,620 t_{dw} in 2007 from a total wastewater flow of 70 MLD. Sludge treatment at this plant was accomplished by storage in aerated lagoons.

Three parameters (copper, molybdenum, and selenium) failed to qualify under the Saskatchewan Guidelines and thus the biosolids may not be land applied. Average trace element concentrations for the biosolids are summarized in Table 17. Applicable benchmark sludge data are also presented for the purpose of comparison.

Table 17. Trace element concentrations and provincial regulatory limits in Saskatchewan

Trace Element	Saskatchewan Biosolids Concentrations (mg/kg)	Benchmark Sludge (mg/kg)	Regulatory Limit (mg/kg)
Arsenic	10.9	-	75
Cadmium	2.5	3	20
Chromium	153	-	1060
Cobalt	5.4	-	150
Copper	803	500	760
Lead	94	200	500
Mercury	2	3	5
Molybdenum	37	-	20
Nickel	44	40	180
Selenium	28	-	14
Zinc	803	1,000	1,850

Biosolids management options

Because some parameters for the biosolids exceed the maximum acceptable concentrations in sewage sludge outlined in the provincial guidelines, land application is not an option. The WWTP locally composts all biosolids produced and prefers this management option due to its cost-effectiveness and simplicity.

Management of the benchmark sludge

While the maximum agronomic application rate will depend on site, crop, desired yield, and climate, rate estimates for two potential application situations are presented in Table 18. These application rate calculations assume that the benchmark total nitrogen concentration of 3.5% is composed of primarily organic nitrogen with negligible contributions of ammonium and nitrate nitrogen.

Table 18. Agronomic application rate of the benchmark sludge in two cropping systems in Saskatchewan

	Crop Uptake (kg N/ha/yr)[1]	Agronomic Application Rate (dt/ha)
Wheat	94[1]	28
Canola	107[1]	30

[1] N demand adopted from AARD, 2008[a], yields adopted from Government of Saskatchewan, 2007.

Trace element concentrations in the benchmark sludge are below provincial maximum acceptable concentration limits for wastewater sludge (Saskatchewan Agriculture, 2004) (see Table 28). Based on the benchmark soil, the maximum allowable application rate is 190 dt/ha and is limited by the copper concentration when considering application to agricultural land (see Table 19). Other uses, such as forest fertilization, land reclamation, composting, incineration, or landfilling would require a permit issued by Saskatchewan Environment.

Table 19. Maximum land application rate of benchmark sludge in Saskatchewan

Trace Element	Concentration in Biosolids (mg/kg)	Pre-application Soil Concentration (mg/kg)	Estimated Post-application Soil Concentration (mg/kg)	Provincial Limit (mg/kg)		
				Agricultural Use	Commercial Use	Industrial Use
Cadmium	3	0.10	0.4	1.4	22	22
Copper	500	10	62.8	63	91	91
Lead	200	20	41.1	70	260	600
Mercury	3	0.05	0.37	6.6	24	50
Nickel	40	15	19.2	50	50	50
Zinc	1,000	40	145.6	200	360	360

Application rate: 190 dt/ha
Soil bulk density: 1,200 kg/m³
Soil depth: 0.15 m

Economic indicators

Economic indicators and biosolids treatment and management costs as a proportion of capital, operating and maintenance costs were averaged for the province and are summarized in Table 20.

Table 20. 2007 average economic indicators and treatment and management costs in Saskatchewan (Canadian dollars)

Cost per Customer to Treat 1 m³ of Wastewater	Cost of 1,000 L Diesel	Cost of 1 kwh of Electricity	% of Annual Sewage Treatment Costs Attributed to Biosolids	
			Capital (%)	O & M[1] (%)
$0.85	$1,277	$0.06	0%	25%

[1] Operations and maintenance costs.

MANITOBA

Manitoba has a population of 1.2 million and a land base of 554,000 km^2. The southern regions of Manitoba support extensive agriculture while the northern regions range from boreal forest to tundra in the northernmost sections of the province. Average January temperature in Manitoba ranges from -27 to -18°C; average July temperatures range from 12 to 18°C. Average annual precipitation across the province is 398 mm of rainfall and 133 mm of snow.

Regulatory review

There are currently no provincial regulations governing biosolids production or use in Manitoba. Biosolids application licenses are issued by Manitoba Conservation (MC) to generators on a case-by-case basis. This review is based on the Land Application of Biosolids License for the City of Brandon, Manitoba (Manitoba MoE, 2001), following the assumption that it is representative of such licenses generally. This license specifies:

- withdrawal, handling, and transport of biosolids;
- the type of land to be applied to;
- a requirement for application plans to be drawn up 30 days prior to application;
- application methods (injected or covered);
- a maximum annual application rate;
- a maximum nutrient loading rate;
- a minimum waiting period to pasture cattle on application sites;
- crop restrictions on application sites;
- maximum trace element loading rates;
- odour management requirements;
- emergency response plan requirements; and,
- monitoring and analysis programs.

An application report must be submitted to MC annually be March 15th and must contain details of the biosolids application program, the amount of nitrogen, phosphorus and potassium added per hectare, results of biosolids, soil, and reference materials analyses, a copy of the analytical procedures used, and the type of crops grown on land for the three years following application.

Table 21 below provides a summary of the analytical requirements for biosolids and the receiving soil.

Table 21. Analytical requirements for biosolids and soil in Manitoba

Biosolids	Soil
arsenic	arsenic
cadmium	cadmium
chromium	chromium
copper	copper
lead	lead
mercury	mercury
nickel	nickel
zinc	zinc
ammonia nitrogen	bicarbonate-extractable phosphorus
conductivity	pH
nitrate nitrogen	potassium
organic nitrogen	sodium
pH	
potassium	
sodium	
total phosphorus	
total Kjeldahl nitrogen	
total solids	
volatile solids	

The permit also requires an additional quality assurance program in addition to those regularly performed by analytical laboratories. For every set of ten samples, a sample of a reference material (either a manufactured sludge or a soil) is also submitted. If the reported value from the analysis of the reference material falls outside an acceptable range (see Table 22), sample analyses must be repeated.

Table 22. Acceptable error ranges for selected biosolids or soil quality parameters

Trace Element	Acceptable Error Range
Arsenic	± 35 percent from the reference value
Cadmium	± 25 percent from the reference value (for values above 1 μg/g)
Cadmium	± 35 percent from the reference value (for values below 1 μg/g)
Chromium	± 25 percent from the reference value
Copper	± 25 percent from the reference value
Lead	± 25 percent from the reference value
Mercury	± 35 percent from the reference value
Nickel	± 25 percent from the reference value
Zinc	± 25 percent from the reference value

In addition, licenses and application rates must conform to the recently promulgated *Nutrient Management Regulation* (NMR) (Government of Manitoba, 2008), which limits macronutrient land application in Manitoba. Application of nitrogen and phosphorus is limited based on land type, as defined under the heading "Soil Capability Classification for Agriculture" in The Canada Land Inventory Report No. 2 (Environment Canada, 1969). Table 23 summarizes restrictions on the use of these macronutrients.

Table 23. Macronutrient land application restrictions under the NMR

Macro-nutrient	Zone[1]	Restriction
N	N1	maximum residual soil N concentration to 0.6 m of 157.1 kg/ha
	N2	maximum residual soil N concentration to 0.6 m of 101 kg/ha
	N3	maximum residual soil N concentration to 0.6 m of 33.6 kg/ha
	N4	No application permitted
P	N1-3	Maximum application of two times the phosphorus removal rate if soil levels are 60-120 ppm
		Maximum application of the phosphorus removal rate if soil levels are 120-180 ppm
	N4	No application permitted

[1] Zones are defined in the NMR and comprise specific soil classes and subclasses as listed under the heading "Soil Capability Classification for Agriculture" in The Canada Land Inventory Report No. 2 (Environment Canada, 1969)

The NMR also restricts application within a "nutrient buffer zone" (minimum safe distances to features such as groundwater, ditches, and bogs, wetlands, or marshes), discharge to water bodies, and application between November 10 and April 10, although exceptions can be made for wastewater sludge or biosolids applications.

Biosolids production and quality

Two WWTPs were surveyed in Manitoba, representing 62% of the provincial population. The two WWTPs surveyed produced a total 13,745 t_{dw} in 2007 from a total wastewater flow of 333 MLD. One of the WWTPs employed lagooned storage as a treatment process, while the other used mesophilic anaerobic digestion. Manitoba has neither provincial regulations governing biosolids management nor any specific trace element quality criteria for sludge or biosolids. If biosolids are marketed for public sale as a fertilizer product, they must conform to the limits in the *Federal Fertilizer Act*.

Biosolids management options

Seventy-five percent of biosolids are applied to agricultural land under license while the remaining 25% is disposed of in landfills. While agricultural application was cited as a preferred management option due to the sustainability of practice and its value as a resource, one generator plans to decrease agricultural applications while increasing landfilling, and the other is forecasting an increase in application to agricultural land (see Table 24).

Table 24. Current biosolids management trends and five-year forecast in Manitoba

Option	% of BS Production	% of Respondents	Forecast
Application to agricultural land	75%	100%	50% to increase
			50% to decrease
Disposal to landfill	25%	50%	50% to increase

Management of the benchmark sludge

While the maximum agronomic application rate will depend on site, crop, desired yield, and climate, rate estimates limited by crop nutrient uptake for two potential application situations are presented in Table 25. These application rate calculations assume that the benchmark total nitrogen concentration of 3.5% is composed of primarily organic nitrogen with negligible contributions of ammonium and nitrate nitrogen.

Table 25. Agronomic application rate of the benchmark sludge in two cropping systems in Manitoba

	Crop Uptake (kg N/ha/yr)[1]	Agronomic Application Rate (dt/ha)
Wheat	94	28
Canola	107	30

[1] N demand adopted from AARD, 2008[a], yields adopted from Manitoba Agriculture, 2008.

In the absence of provincial regulations specifying maximum allowable constituent concentrations, management of the benchmark sludge is constrained by the maximum cumulative weight per hectare trace element limits specified in the Land Application License granted by Manitoba Conservation. From a trace element perspective based on the benchmark soil, the maximum annual application rate is 190 dt/ha and is limited by the copper concentration (see Table 26).

Table 26. Maximum benchmark sludge land application rate based on trace element limits in Manitoba

Trace Element	Biosolids (mg/kg)	Pre-application soil (mg/kg)	Estimated post-application soil (kg/ha)	Provincial Limit (kg/ha)
Cadmium	3	0.10	0.8	2.5
Copper	500	10	113	113.4
Lead	200	20	74	126
Mercury	3	0.05	0.7	11.9
Nickel	40	15	34.6	90
Zinc	1,000	40	262	360

Application rate: 190 dt/ha
Soil bulk density: 1,200 kg/m^3
Soil depth: 0.15 m

Economic indicators

Economic indicators and biosolids treatment and management costs as a proportion of capital, operating and maintenance costs were averaged for the province and are summarized in Table 27.

Table 27. 2007 average economic indicators and treatment and management costs in Manitoba (Canadian dollars)

Cost per customer to treat 1 m^3 of wastewater	Cost of 1,000 L diesel	Cost of 1 kwh of electricity	% of annual sewage treatment costs attributed to biosolids	
			Capital (%)	O & M[1] (%)
$0.70	$1,029	$0.06	25%	28%

[1] Operations and maintenance costs.

SUMMARY OF THE BENCHMARK SLUDGE BY PROVINCE

The benchmark sludge does not exceed maximum allowable trace element concentrations stipulated under BC and Saskatchewan regulations, is above minimum allowable nitrogen-to-trace element ratios specified in the Alberta regulations, and is below maximum allowable soil trace element concentrations as provided in the Manitoba regulatory framework. Table 28 below summarizes the comparison of the benchmark sludge quality to the regulatory criteria stipulated by the four western Canadian provinces.

Table 28. Performance of the benchmark sludge under trace element criteria according to provincial regulations

			BC		AB			MB	
Parameter	Units	Bench-mark Sludge	Class A	Class B	Ratios of benchmark	Mini-mum ratio	SK	Soil Levels at <190 dt/ha	Soil Limits (kg/ha)
Cadmium	mg/kg	3	20	20	11,667	1,500	20	0.8	2.5
Copper	mg/kg	500	-	2,200	70	15	760	113	113.4
Lead	mg/kg	200	500	500	175	20	500	74	126
Mercury	mg/kg	3	5	15	11,667	3,000	5	0.7	11.9
Nickel	mg/kg	40	180	180	875	100	180	34.6	90
Zinc	mg/kg	1,000	1,850	1,850	35	10	1,850	262	360
Acceptable	-	N/A	Yes	Yes	N/A	Yes	Yes	N/A	Yes

INDIVIDUAL BIOSOLIDS GENERATOR DATA

Information used in developing this submission was collected through the distribution of a survey and a review of applicable regulations. Completed copies of the surveys from each jurisdiction are provided at the end of this document.

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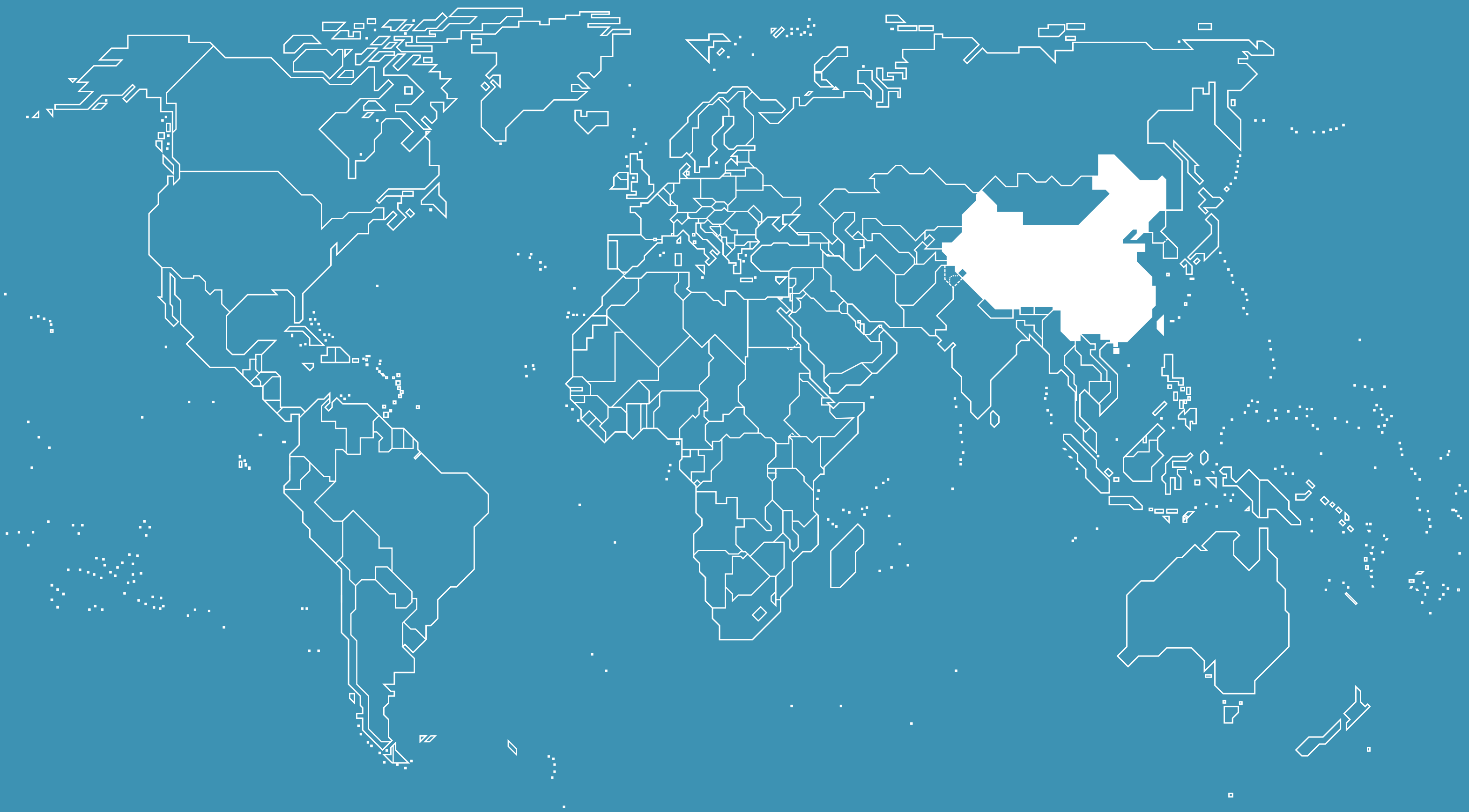
Before and after – Land application on farm. Photo © GMSC



China

Management of sewage sludge in urban areas

THE RAW BENCHMARK SLUDGE

Population equivalent

In 2006, the sewage production in urban areas of China was 2.966×10^{10} tons, 5.4% higher than that in 2005. The sewage production rate was 0.17 m^3/d·capita. A total of 43.8% of sewage was treated in 939 WWTPs. The dry sludge production is only 0.01~0.014% of the treated sewage.

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Raw sludge thickened, on dry solids

The benchmark values of sludge are listed in Table 1. The legally controlled values of sludge before being discharged out of WWTPs are also given in Table 1.

Table 1. Benchmark value and controlled value of sludge characteristics in China

Parameters	Unit	Benchmark value[1), 2)]	Controlled value*
Dry solids	per thickened sludge	3%-7%	-
Organic matter	g/kg-dry sludge	404±129	-
Zn	mg/kg-dry sludge	1370±1230	< 4000 [4)]
Cu	mg/kg-dry sludge	1180±2440	< 1500 [4)]
Ni	mg/kg-dry sludge	193±530	< 200 [4)]
Hg	mg/kg-dry sludge	2.75±1.75	< 25 [4)]
Cd	mg/kg-dry sludge	10.9±35.0	< 20 [4)]
Pb	mg/kg-dry sludge	126±134	< 1000 [4)]
Total nitrogen	g/kg-dry sludge	36.0±13.2	-
P_2O_5	g/kg-dry sludge	40±18	-
K_2O	g/kg-dry sludge	5.6±2.4	-
pH	-	7.31±0.57	5-10 [4)]
Water content	-	79.7±4.9 %	< 80 % [3),4)]
Fecal coliforms	-	-	>0.01 [4)]
Bacteria number	MPN/kg-dry sludge	-	< 10^8 [4)]
Cr	mg/kg-dry sludge	302±648	< 1000 [4)]

Parameters	Unit	Benchmark value[1), 2)]	Controlled value*
As	mg/kg-dry sludge	5.86±14.5	< 75 [4)]
Mineral oil	mg/kg-dry sludge	-	< 3000 [4)]
Volatile phenol	mg/kg-dry sludge	-	< 40 [4)]
Total cyanide	mg/kg-dry sludge	-	< 10 [4)]
Dewatering	-		Required [3), 4)]
Stabilization	-		Required [3), 4)]

** The quality of sewage sludge discharged out of WWTPs should meet the controlled values required in the standards GB18918-2002 and CJ247-2007 (references 3 and 4).*

1. *Jiangsu Province Government (2006). Strategy study on the treatment technologies for sludge from municipal wastewater treatment plant.*
2. *He P J, Lü F, Zhang H, Shao L M, Lee D J. Sewage sludge in China: challenges toward a sustainable future[A]. Proceedings of IWA Specialist Conferences on Moving Forward – Wastewater Biosolids Sustainability: Technical, Managerial, and Public Synergy (accepted for oral presentation) [C]. pp. 39-46. Moncton, New Brunswick, Canada, June 24-27, 2007.*
3. *State Environmental Protection Administration of China. Pollutants discharge standard of municipal wastewater treatment plant in China. National Standard No. GB18918-2002.**
4. *Chinese Ministry of Construction. Sludge characteristics of municipal wastewater treatment plant. Ministerial Standard No. CJ247-2007.*

Maximum permissible concentrations of potentially toxic elements in sewage sludge when applied to soils

Applied soils are classified into acidic, neutral, and alkaline in China. They are usually alkaline (pH 7-8) in the north of China, whereas acidic (pH 5-6) in the south of China. Based on the applications, there is a difference in maximum permissible concentrations of potentially toxic elements in sewage sludge when applied to soils, as follows.

Table 2. Permissible concentrations of toxic elements in sludge when applied to soils.

Items	Unit	Maximum Permissible Concentration		Standard
		pH < 6.5	pH >= 6.5	
Appearance	-	Loose and without obvious smell		3)
pH	-	6.5-8.5	5.5-7.5	3)
Water content	%	<45		3)
Macro-nutrients ($N+P_2O_5+K_2O$)	%	>=4	>=20	3)
Cd	mg/kg-dry sludge	5	20	1),2),3)
Hg	mg/kg-dry sludge	5	15	1),2),3)
Pb	mg/kg-dry sludge	300	1000	1),2),3)
Cr	mg/kg-dry sludge	600	1000	1),2),3)
As	mg/kg-dry sludge	75	75	1),2),3)
Ni	mg/kg-dry sludge	100	200	1),2),3)
Zn	mg/kg-dry sludge	2000	3000	2),3)
Cu	mg/kg-dry sludge	800	1500	2),3)
B	mg/kg-dry sludge	150	150	1),2),3)
Mineral oil	mg/kg-dry sludge	3000	3000	1),2),3)
Benzo(a)pyrene	mg/kg-dry sludge	3	3	2),3)
PCDD/PCDF	ng/kg-dry sludge	100	100	2),3)
AOX	mg/kg-dry sludge	500	500	2),3)
PCB	mg/kg-dry sludge	0.2	0.2	2),3)
Fecal coliforms	-	>0.01	>0.01	3)

		Maximum Permissible Concentration		
Items	**Unit**	**pH < 6.5**	**pH >= 6.5**	**Standard**
Mortality rate of helminth ovum	%	>95	>95	3)
Contagious pathogen	-	undetected		3)
Germination rate index	%	> 70		3)

1. *State Environmental Protection Administration of China. Control Standards for Pollutants in Sludges for Agricultural Use. National Standard No. GB4284-84.*
2. *State Environmental Protection Administration of China. Pollutants discharge standard of municipal wastewater treatment plant in China. National Standard No. GB18918-2002.*
3. *Chinese Ministry of Construction. Sludge Characteristics of gardening from municipal wastewater treatment plant. Ministerial Standard No. CJ248-2007.*

ECONOMICS

Proportion of annual cost (operational and finance charges) of sewage treatment and disposal attributable to sludge treatment and disposal for a typical works of 100,000 p.e.:

About 30%-50% of the total cost of a WWTP on investment and operation. This value is for a typical works of 100,000 m^3/d, because the WWTPs of this scale are common in Chinese cities.

Basic data for calculation[1]

- The cost of sewage treatment is 0.40 RMB[2] per m^3-wastewater (including operation and investment charge).
- The cost of sludge dewatering is 8-12 RMB per m^3-thickened sludge. (The moisture content decreases from 97% to 80%).
- The cost of sludge disposal in MSW landfill is 90-120 RMB per ton-wet sludge (moisture content < 80%).

Charge to customers for treating 1 cubic meter of sewage[3]:

- The charge for 1 cubic meter of sewage ranges from 0.15 to 1.20 RMB, taking an average of 0.56±0.23 RMB in January 2008 in China.

Cost of 1,000 liters of diesel fuel[4]

- The cost of 1,000 liters of diesel No. 0 was 5950~6150 RMB in February 2008 in China.

Cost of one kilowatt hour of electricity[5]

- The price of 1 kWh electricity for residential use ranges from 0.38 to 0.76 RMB, taking an average of 0.52±0.06 RMB in January 2008 in China. The electricity used in WWTPs counts as to industrial use, which costs 1.2 to 1.5 times that for residential use. For example, the price of 1 kWh electricity for residential use in Shanghai in January 2008 was 0.61

1 *Jiangsu Province Government (2006). Strategy study on the treatment technologies for sludge from municipal wastewater treatment plant.*
2 *RMB is the Chinese unit of currency. One euro is equal to about 10.7 RMB.*
3 *China Price Information Network, available at www.chinaprice.gov.cn*
4 *National Development and Reform Commission of China. Available at http://www sdpc.gov.cn/nyjt/*
5 *China Price Information Network, available at www.chinaprice.gov.cn, Shanghai Price Information Service Network, available at www.wj.sh.cn*

RMB from 6:00 to 22:00 and 0.30 RMB from 22:00 to 6:00. The electricity price for industrial use was 0.666 RMB.

DISPOSAL OPTIONS

The land application is the favored option for sludge disposal, considering the disposal cost and environmental benefits. For land application, the potential toxic elements in sludge are of most concern. In China, about 45% and 3.5% of sludge is applied to agriculture and gardening, respectively, after being treated by digestion and dewatering processes. For example, in the city of Shanghai, the sludge is applied to the soils of the outskirts or a neighboring province after dewatering.

The landfill is also one of the major methods for sludge disposal. About 34.4% of sludge is disposed in landfill. However, there is still a shortage of special landfill for sludge, and the sludge is usually disposed in MSW landfill. However, the availability of sanitary MSW landfills in China is low (less than 10%), suggesting that most sludge is dumped or applied into simple landfill sites without strict operational requirements (e.g. HDPE liner, daily cover). The situation is expected to be improved with the promulgation of a new landfill regulation (Table 4, GB16889-2008). Nevertheless, the poor structure of sludge would be unfavorable for the landfill operation; so alternative options to landfill are to be pursued.

Only about 3.5% of sludge is treated by incineration. Usually, the sludge is co-combusted in fluidized beds for coal-burning power plants and industrial boilers. There is only one sludge incinerator located in the Shidongkou WWTP of Shanghai City (220 ton-dry sludge/day, the process is thickening, dewatering, fluidized bed drying and then fluidized bed incineration).

The major points of concern in decision-making are the transportation cost, toxic elements in sludge and landfill capacity. Furthermore, the efficiency and cost of dewatering and drying are important for each disposal option.

MECHANICAL DEWATERING

The sludge needs to be dewatered to decrease moisture content, sludge volume, and transportation cost, as well as treatment and disposal cost. In China, the regulations (Table 4, GB18918-2002 and CJ247-2007) require that the moisture content of sludge must be less than 80% before being discharged out of a WWTP. This means that sludge dewatering is necessary for WWTPs.

In the past, most of sludge was only thickened before land application. With the promulgation of the regulations GB18918-2002 and CJ247-2007, all WWTPs should have been equipped with sludge-dewatering devices starting in 2006.

At present, the major mechanical dewatering process is belt filter, followed by centrifugation and pressure filter.

STABILIZATION OR DISINFECTION TECHNIQUES

The Pollutants Discharge Standard of Municipal Wastewater Treatment Plant in China standard (National Standard No. GB18918-2002) says sludge should be stabilized before being discharged out of a WWTP (it entered into force in 2003 for newly constructed or enlarged WWTPs, and from 2006 for old WWTPs). Detailed requirements are listed in Table 3.

Table 3. Requirements on sludge stabilization (GB18918-2002)

Stabilization process	Controlled parameter	Controlled value
Anaerobic digestion	Organics degradation rate	> 40%
Aerobic digestion	Organics degradation rate	> 40%
Composting	Moisture content	< 65%
	Organics degradation rate	> 50%
	Mortality rate of worm egg	> 95%
	Feces coliform	> 0.01

China's major stabilization or disinfection techniques include anaerobic digestion, aerobic digestion and chemical stabilization. The proportion of sludge composting is quite low

Anaerobic digestion has been extensively adopted. However, its drawbacks are the higher requirement for equipment and lower dewaterability after digestion. Application of aerobic digestion for sludge is lower than that of anaerobic digestion because of higher cost and lower removal efficiency for pathogens. However, it is more common than anaerobic digestion for small WWTPs. The advantages of aerobic digestion are the high digestion effectiveness, the small amount of excess sludge, and the simple operation and management. In contrast, its disadvantages are lowered recovery energy potential and resources, high operational costs, and vulnerability to temperature.

There are, so far, no regulations on chemical stabilization.

Reference:

State Environmental Protection Administration of China. Pollutants discharge standard of municipal wastewater treatment plant in China. National Standard No. GB18918-2002.

RULES AND REGULATIONS

The regulations related to sludge management in China are listed in Table 4.

Table 4. List of the active regulations related to sludge management in China

Code	Title	Level	Category	Requirements
GB18918-2002	Pollutants Discharge Standard of Municipal Wastewater Treatment Plant in China	National	Discharge control Dewatering	Table 1
CJ247-2007	Sludge Characteristics of Municipal Wastewater Treatment Plant	Ministerial	Discharge control Dewatering Stabilization	Table 1 Table 2 Table 3
CJ/T239-2007	Classification of the Technologies for Sludge Disposal	Ministerial	Classification of disposal options	-

Code	Title	Level	Category	Requirements
GB4284-84	Pollutants Control Standard of Sludge for Agricultural Application	National	Land application	Table 2
CJ248-2007	Sludge Characteristics of Gardening from Municipal Wastewater Treatment Plant	Ministerial	Land application	Table 2
CJ/T249-2007	Sludge Characteristics of Landfill with Municipal Solid Waste from Municipal Wastewater Treatment Plant Disposal	Ministerial	Landfill	Table 5 Table 6
GB16889-2008	Standard for Pollution Control on the Landfill Site for Domestic Waste	National	Landfill	Table 3
-	In preparation	-	Construction materials	-
-	In preparation	-	Incineration	-
-	In preparation	-	Drying	-

The quality of sludge before being discharged out of WWTPs was regulated in the "Wastewater and Sludge Disposal Standard for Municipal Wastewater Treatment Plants" (Ministerial Standard No. CJ3025-93), which was replaced by the "Pollutants Discharge Standard of Municipal Wastewater Treatment Plant in China" (National Standard No. GB18918-2002). GB18918-2002 formulated that the sludge had to be dewatered to a moisture content of less than 80% and stabilized. On Jan 29, 2007, a new regulation "Sludge Characteristics of Municipal Wastewater Treatment Plant" (Ministerial Standard No. CJ247-2007) was issued and formulates the pollutants limits of sewage sludge discharged out of wastewater treatment plants.

On Jan 29, 2007, the Chinese Ministry of Construction released a new standard of "Classification of the Technologies for Sludge Disposal" (Ministerial Standard No. CJ/T239-2007). The major disposal manners for sludge in the new standard are classified into four types: land application, landfill, production of usable materials and incineration.

The land application of sludge was divided into gardening, land reclamation and agriculture application. The rules and regulations related to the land application are "Pollutants Control Standard of Sludge for Agricultural Application" (National Standard No. GB4284-84), "Pollutants Discharge Standard of Municipal Wastewater Treatment Plant in China" (National Standard No. GB18918-2002) and "Sludge Characteristics of Gardening from Municipal Wastewater Treatment Plant" (Ministerial Standard No. CJ248-2007). The standard of "Control Standards for Pollutants in Sludges for Agricultural Use"(GB4284-84) was released in 1984. In this standard, the maximum permissible concentrations of some metals (such as Cu and Zn) are need to be re-formulated. Meanwhile, there is an absence of pathogens in this standard. The aim of "Pollutants Discharge Standard of Municipal Wastewater Treatment Plant in China" (GB18918-2002) is a comprehensive pollutant discharge standard. It therefore lacks specific instructions on land application of sludge. The new standard "Sludge Characteristics of Gardening from Municipal Wastewater Treatment Plant" (CJ248-2007) was released on Jan 29, 2007, and came into effect on Oct 1, 2007 on. It regulates in more detail the characteristics, sampling and monitoring techniques for sludge applied to gardening. The characteristics include sludge appearance, smell, stabilization, nutrition, pathogens, heavy metals, etc.

The regulation related to sludge landfill is "Sludge Characteristics of Landfill with Municipal Solid Waste from Municipal Wastewater Treatment Plant Disposal" (Ministerial Standard No.

CJ/T249-2007). It regulates the sludge characteristics, sampling and monitoring requirement of landfill operation and landfill covering soil. The detailed requirements are listed in Table 5 and Table 6. When sludge is disposed in MSW landfill site, it should also meet the MSW landfill standard GB16889-2008 (Table 4), which says the moisture content of sludge must be less than 60%.

Table 5. Requirements on the disposal of sludge in MSW landfill site (CJ/T249-2007)

Parameter	Unit	Controlled value
Moisture content	-	≤ 60%*
pH	-	5-10
Mixing rate of sludge to MSW	-	≤ 8%
Cd	mg/kg-dry sludge	< 20
Hg	mg/kg-dry sludge	< 25
Pb	mg/kg-dry sludge	< 1000
Cr	mg/kg-dry sludge	< 1000
As	mg/kg-dry sludge	< 75
Ni	mg/kg-dry sludge	< 200
Zn	mg/kg-dry sludge	< 4000
Cu	mg/kg-dry sludge	< 1500
Mineral oil	mg/kg-dry sludge	< 3000
Volatile phenol	mg/kg-dry sludge	< 40
Total cyanide	mg/kg-dry sludge	< 10

* *Also required in the standard GB 16889-2008.*

Table 6. Requirements on the sludge as the cover soil of MSW landfill (CJ/T249-2007)

Parameter	Unit	Controlled value
Moisture content	-	< 45%
Odor	-	Less than the level 2^{nd}
Density of fly after application	per day per box	< 5
Transverse shear	kN/m^2	> 25
Fecal coliforms	-	> 0.01
Mortality rate of helminth ovum	-	> 95%
Contagious pathogen	-	Undetected

The regulation related to the sludge applied as the construction materials has not been released to date. However, it was listed in the agenda of Chinese Ministry of Construction in 2007. The regulations about sludge drying and incineration are under preparation. They were listed in the planning of Chinese Ministry of Construction in 2007. In fact, the standard "Technology code for sludge treatment of municipal wastewater treatment plant" has been drafted and now is waiting for public feedback.

By the way, the above regulations are only the beginning of standardizing sludge management in China. According to planning by responsible agencies (State Environmental Protection Administration of China and Chinese Ministry of Construction) a series of sludge management standards will be developed to achieve the goals of sludge reduction, stabilization and resource recovery.

PRACTICAL CONSTRAINTS THAT AFFECT OPERATIONS

Thickening and dewatering. In the past, most of sludge was only thickened and then transported for land application. Only a minor portion of sludge was thickened and dewatered. However, with the promulgation of the standards GB18918-2002 and CJ247-2007 (Table 4), all WWTPs have been required to dewater their sludge to a moisture content of 80% since 2006 on. Furthermore, because more and more WWTPs use the wastewater treatment process of prolonged sludge age (e.g. oxidation ditch), the sludge will be dewatered without thickening. The efficiency of dewatering technology is of concern.

Stabilization. Few WWTPs used the operation of stabilization, before the promulgation of standard GB18918-2002 (Table 4). After the standard was formulated, all WWTPs were required to stabilize their sludge before discharged out of WWTPs after 2006. This means that WWTPs should establish stabilization systems, e.g. anaerobic digestion, aerobic digestion or composting. However, the continuous operation of these stabilization systems greatly depends on finances, which constrains implementation of stabilization.

Composting and land application. The quality of sludge-derived products (e.g. content of heavy metals) and the product market contrain sludge composting and land application.

Landfill. Most of sludge by "landfill" is disposed of in simple MSW landfill sites or by dumping. Since the amount of MSW sanitary landfill sites is small, development of MSW sanitary landfill in China will also affect the operation of sludge co-landfill with MSW. Furthermore, the efficiency of dewatering and drying will limit the sludge landfill, because the standards CJ/T249-2007 and GB16889-2008 require the moisture content of landfilled sludge to be below 60%. Another constraint is the structure of sludge, which leads to a small mixing rate of sludge to MSW (only 8%) (Table 5).

Drying and incineration. The cost of sludge drying and incineration is the major factor influencing their application.

Above of all, for each sludge disposal option, the high moisture content of sludge is the major practical constraint. The high moisture content reduces the landfill capacity, impairs the efficiency of incineration and composting. Therefore, the effectiveness and efficiency of dewatering and drying are of foremost importance.

DESCRIPTIONS OF OPERATIONS

Land application. In China, land application of sludge is encouraged and about 48% of sludge is applied to agriculture and gardening. In the past, thickened sludge was transported to land and applied by ploughing. With the promulgation of the standard GB18918-2002 (Table 1, Table 4), dewatered sludge (with stabilization) is applied to land by mechanical ploughing. The control of pollutants in sludge and the quantity and method for sludge land application are of major concern. Based on the standard GB4284-84 (Table 2, Table 4), the dry sludge amount applied to soil must be less than 30,000 kg per hectare per year. Additionally, the duration of sludge application should be less than 20 years when one of inorganic items in sludge approaches to the upper limit of standard value. The standard also states that the sludge should not be applied to the land around drinking water source. The raw sludge should not be applied to land unless that it has been stabilized by thermophilic composting or digestion treatment. The sludge can be applied to the agriculture, gardening and flower land, but cannot be applied to vegetable or herd land. As for acidic soil, the applied sludge must meet the maximum permissible concentration of the standard; furthermore, lime should be applied to adjust the pH of the land soils. When the pollutants in the land soils approach to the maximum permissible concentration, the amount of applied sludge should be reduced.

Landfill. The sludge landfill is divided into solely landfill, landfill with municipal solid waste and special landfill. When sludge is disposed in a MSW landfill site, it should meet the requirements of the standards CJ/T249-2007 and GB16889-2008 (Table 4, Table 5, Table 6).

Incineration. The sludge incineration includes solely incineration, mixed with municipal solid waste, electrical power plant and industrial boiler The incineration systems are usually fluidized bed furnaces. Considering the heat recovery in the incineration systems, the sludge is not recommended to be pre-treated by anaerobic or aerobic digestion before entering the incineration systems. The moisture content of sludge should be controlled to lower than 30% before it is incinerated.

Stabilization. The requirement on stabilization is listed in the standard GB18918-2002 (Table 3, Table 4). The moisture content of sludge after composting and the value of feces coliform must be less than 65% and 0.01, respectively. The organic degradation rate and mortality rate of worm egg should be above 50% and 95%, respectively. The organic degradation rate in anaerobic and aerobic digestion should above 40%.

References:

State Environmental Protection Administration of China. Control standards for pollutants in sludges for agricultural use. National Standard No. GB4284-84.

Chinese Ministry of Construction. Technology code for sludge treatment of municipal wastewater treatment plant. Ministerial Standard (Draft).

State Environmental Protection Administration of China. Pollutants discharge standard of municipal wastewater treatment plant in China. National Standard No. GB18918-2002.

BOTTOM LINES FOR THE BENCHMARK SLUDGE

Strategic selection of disposal practice – what would probably be done with it and any biosolids derived from it. Agricultural use is the focus of the Atlas and is the prime target for information and on that basis, the answers given in response to other options below will be in lesser detail

- Land application is encouraged in China, The control of pollutants (e.g. heavy metals, POPs and EDs) in sludge and the quantity and method for sludge land application are of major concerns.

ECONOMIC INFORMATION

- The cost for land application or landfill is about 150-200 RMB/ton-dewatered sludge (corresponding to 0.13-0.18 RMB/m^3-sewage). The cost for incineration or drying is about 250-300 RMB/ton-dewatered sludge (corresponding to 0.15-0.20 RMB/m^3-sewage).

How would you conduct landfill, including the use of sacrificial land?

- There is still a scarcity of regulation and practice for sludge special landfills in China.
- Sludge landfill is mostly practiced as disposal in MSW landfill site, where sludge is taken as landfilled waste or cover soil. If sludge is taken as waste, it should meet the requirements of the standards GB16889-2008 and CJ/T249-2007 (Table 4, Table 5). If sludge is taken as cover soil, it should meet the requirements of CJ/T249-2007 and GB16889-2008 (Table 4, Table 6).
- The use of sludge in sacrificial land is under discussion, and there isn't any practice yet.

How would you conduct incineration including vitrification? Specify whether it would be incinerated with other wastes

- As for sludge incineration, only about 3.5% of sludge is treated by incineration in China now. Usually, the sludge is co-combusted in the fluidized beds of coal burning power plant and industrial boilers. There is only one sludge incinerator located in the Shidongkou WWTP of Shanghai City (220 tons of dry sludge/day, the process is thickening, dewatering, fluidized bed drying and then fluidized bed incineration). A plant for the co-incineration of sludge and MSW is under construction in Guangdong Province. The residues (bottom ash) of sludge incineration are landfilled or processed as construction materials.

How would you manage use on arable land? Please assume typical staple crops – examples are maize (corn), wheat, oats/barley, sugar beet, soya beans, forage crops, industrial crops. If the land is in regions growing fruit and vegetable crops or other crops consumed raw by humans (such as nuts) – please explain

- The land application of sludge is regulated by the standards GB4284-84, GB18918-2002 and CJ248-2007 (Table 2, Table 4). Although the standards haven't formulated the land types for sludge application, it is generally considered that sludge should not be applied to the arable lands relevant to food web. That is to say, the lands for landscape, horticulture and woodland would be preferable.

How would you conduct conversion wholly or in part into a product to be used in the domestic or horticultural market e.g. lawns, parks and playing fields?

- The sludge meeting the standards GB4284-84, GB18918-2002 and CJ248-2007 (Table 2, Table 4) can be applied to the domestic or horticultural market.
- The general conversion process is composting.
- If the treated sludge is value-added as organic fertilizer, it should meet the standard of "Organic-Inorganic Compound fertilizer" (National Standard No. GB18877-2002).

How would you conduct use in forests/woodland, on conservation and non sporting recreation land, for land reclamation?

- The requirements and conversion processes are the same as the above of domestic or horticultural market.

How would you conduct production of by products e.g. vitrified glass products, construction materials, fuel pellets, oil, protein etc.

- The sludge is made to construction materials after drying or incineration. The drying sludge used to make bricks needs to mix with clay. The incinerated sludge used to make bricks needs to mix with silica or clay. The feasibility of sludge as construction materials has been studied a lot, but there is little industrial practice.
- In all, more versatile value-added products from sewage sludge are expected. But the technologies are under study and far from industrial scale application, compared to traditional disposal processes. Furthermore, the product quality, high price and immature market are also bottlenecks for producing value-added products from sludge.

Reference:
He PJ, Gu GW, Lee DJ. Municipal Sludge Treatment and Utilization. Beijing: Science Press, 2003, pp 244-255.

FAECAL WASTE

In some Chinese mega-cities, e.g. Shanghai, faecal waste is discharged into the sewage collection system and then transported into WWTP, while in most urban areas, the faecal waste after pre-treatment (e.g. septic tank) is transported to rural areas for land application.

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Hong Kong Special Adminstrative Region (of China)

BACKGROUND

Hong Kong is a city with population of approximately 6.9 million. The government Drainage Services Department (DSD) is responsible for the sewage collection and treatment services for the city. The public sewerage system covers 93% of the population and collects about 2.68 million m^3 of wastewater every day. The collected sewage is treated in 69 sewage treatment plants in different locations in the city, of which 30% receives preliminary treatment, 53% receives chemically enhanced primary treatment (CEPT) and 17% receives secondary treatment.

Most of the sludge produced is de-watered and disposed of at landfills, currently the only disposal means of de-watered sludge in Hong Kong. The daily quantity of de-watered sludge disposed of is about 864 tonnes.

SELECTION OF DISPOSAL PRACTICE

Since sewage treatment and waste disposal services in Hong Kong are provided by the government, the disposal practice of sewage sludge follows the government policy. At present the de-watered sludge produced is disposed of at landfills. However, the government is proposing to build an incinerator (anticipated to begin operation in 2012) for disposal of the de-watered sludge with grease trap wastes, because of problems in the following areas:

Co-disposal: sludge is currently co-disposed of at landfill sites with municipal solid waste (MSW). It is expected that the sludge/MSW disposal ratio will increase in the future, which could cause landfill instability

Limited landfill life: landfill space will be exhausted soon and landfill disposal of sludge worsens the situation

Biodegradable waste: disposal of biodegradable waste (including sludge) at landfills is not considered a sustainable waste management practice and not in line with the worldwide trends

ECONOMIC INFORMATION

- Annual cost of sewage treatment/disposal and sludge treatment/disposal: such information can not be retrieved from the public domain
- Sewage charge: at present the government subsidizes a significant portion of sewage treatment cost. Nevertheless, the sewage charge will rise from the present rate of $HKD1.20/$m^3$ to $HKD 2.92/$m^3$ in 2017
- Diesel fuel cost: $HKD9,920 /1,000L (retail price, government duty inclusive)
- Electricity cost: electricity is provided by two companies in Hong Kong. The unit prices (per kWh) are $HKD1.15 and $HKD0.88

AGRICULTURAL USE OF BIOSOLIDS

Since the de-watered sludge is disposed of in landfills, there is currently no large operation turning sludge into biosolids. Also, agricultural land accounts for less than 1% of Hong Kong's total area, and therefore the market for agricultural use of biosolids is very small.

Note: The author is not associated with Hong Kong government departments that provide sewage treatment and waste disposal services. The information above is from documents and other public domain materials.

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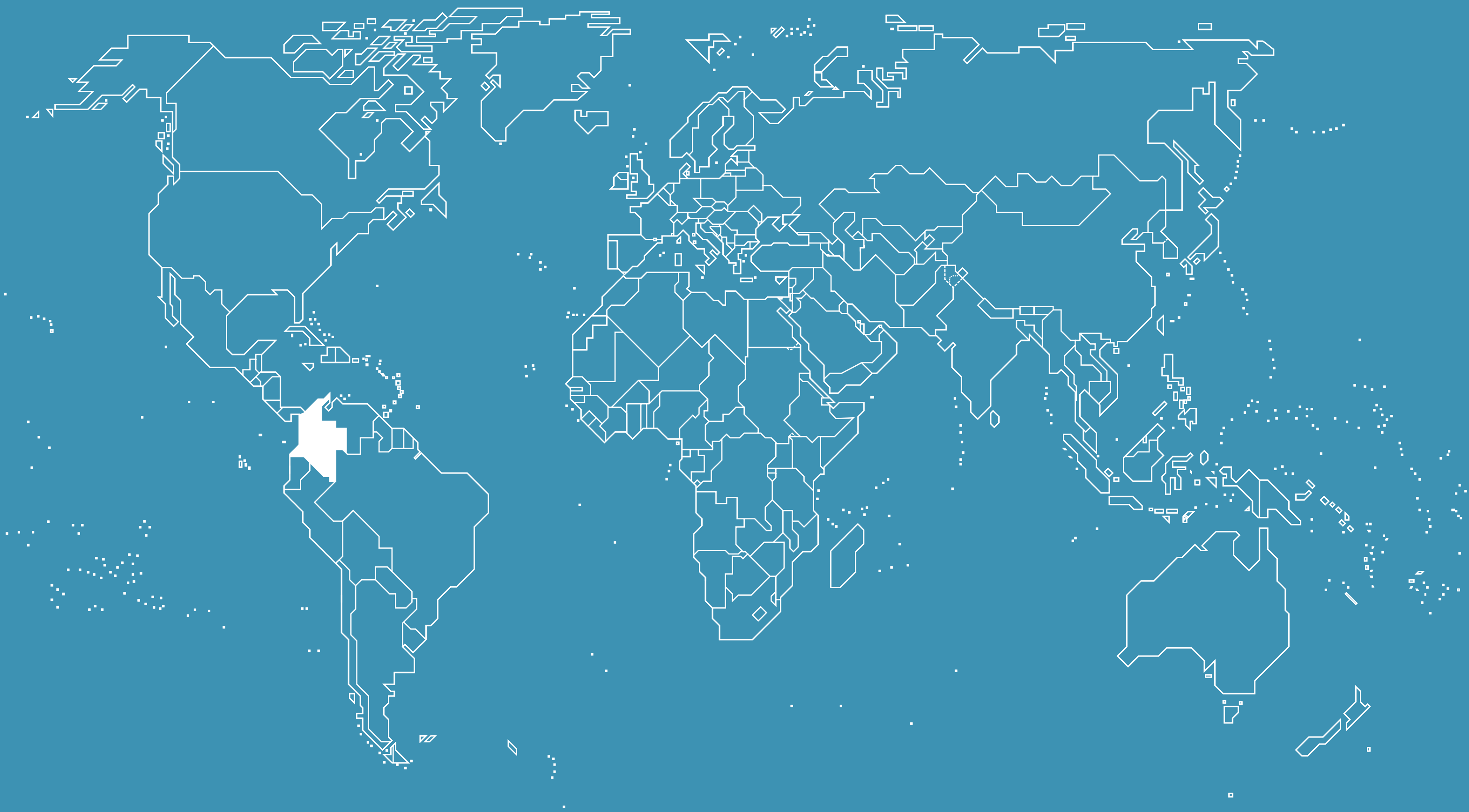

Colombia

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Biosolids management in wastewater facilities – El Salitre, Bogotá

INTRODUCTION

In Colombia, domestic and industrial residual water production has been growing along with the population and productive development, increasing contaminated water spill into surface sources. Nevertheless, in Colombia only 5 to 10% of the largest municipalities carry out any type of wastewater treatment, which is one of the main influences on the quality of the surface water supply. The existing infrastructure for domestic wastewater treatment serves only 7.72% of the urban population.

Colombia is estimated to generate 5 million cubic meters of wastewater discharge every day, containing organic loads of 1.500 tons coming from domestic sources, and approximately 500 tons from industrial sources at urban centers. The agricultural organic loads are calculated in 7.200 tons per day, mostly coming from farming sectors such as coffee and banana raising.

The infrastructure for wastewater treatment is still unreliable. According to the national sanitary inventory, carried out by the Department of Economic Development in 1998, the country depends on 133 municipal water treatment systems. Although the number of wastewater facilities is known, few are functioning and, with a small number of exceptions, there is not enough data on the effluent quality. The wastewater treatment systems coverage does not surpass 5 % in the urban population.

In the last 8 years, in main cities such as Bogota, Medellin and Cali, wastewater treatment facilities have been constructed for wastewater coming from domestic sources. In the case of Bogota (the country's capital), a facility for primary treatment was constructed in 2000, with the following characteristics:

Population attended:	2.200.000 habitants	
Type of treatment:	Advance primary chemically assisted	
Flow volume Operation	Media: 4.0 m^3/s	Maximum: 9.9 m^3/s
Removal efficiency:	SST: 60%	DBO5: 40%
Sludge stabilization:	Anaerobic mesophilic treatment	
Biogas generation	15000 – 20000 m^3/d	
Biosolid generation:	165 ton/d used for zone replenish of the sanitary landfill Doña Juana. (SLDJ)	

The treatment system is managed by the Empresa de Acueducto y Alcantarillado de Bogotá.

Sludge treatment consists of the following phases:

1. *Primary Sludge Pumping Buildings*: 73.9 tons of sludge decanted as dry matter is produced every day (approximately 7,400 m^3 of primary sludge with 99% water). For every two primary decanters there is a station with submersible pumps that sends the sludge into the thickening stage. The sludge extraction from the decanters is done automatically through pneumatic valves.
2. *Primary Sludge Thickeners*: In order to increase sludge concentration before digestion, two units have been installed with the following dimensions: 29 m in diameter and 4.0 m in lateral height. The thickeners allow regulation of the sludge supply into the treatment (anaerobic digestion). Water that is withdrawn from the sludge is returned into the plant. The thickeners are also equipped with sweeps that direct the sludge to the central exit at the bottom of the equipment.
3. *Pumping Building*: the thickened sludge, with a solid concentration of approximately 6 to 10%, is extracted and sent to a recollecting well from which it's pumped into digesters.
4. *Sludge Digesters*: The biological stabilization of the primary sludge is produced in three 8500 m^3 digesters at a temperature of 35° C where digestion takes place after 22 days (every day 51.6 tons of digested sludge as dry matter is produced, equivalent to 1320 m^3 with 96% humidity). A homogeneous sludge mixture is achieved by means of gas agitation. The biogas produced is recycled and injected into the center of each digester, assuring contact between the digested and raw sludge.
5. *Warming premises*: the plant uses its own energy, generated by combusting biogas. The sludge is warmed in tubular countercurrent exchangers of water and sludge.
6. *Storage of the digested sludge*: the digested sludge is stored in a tank equipped with submersible agitators from which it's directed to the dehydration process. An open circular structure with a functional volume of 2.700 m^3 has been constructed with enough capacity for first and second phases.
7. Sludge Dehydration: to reduce volume and facilitate transport the digested sludge is dried. The process involves sending the sludge from the ditch or compilation tank to the dehydration building where a group of filters is located. In five filtration units the dehydration is done until a semisolid consistency is achieved (sludge cake), with a concentration of solids of approximately 30 %. Every day 165 tons are produced with a humidity of 65 %.
8. Gas metering: at standard conditions between 15.000 and 20.000 m^3 of biogas is produced every day. The biogas is re-used for digester agitation and for the boilers. An inflatable gas meter of 300 m^3 has been installed, for biogas storage.
9. Torching: the excess gas is burned by a torch.

In sludge treatment the major difficulties relate to residual water quality, generation of low quality sludge, problems in controlling the pH and generating volatile fatty acids (VFA) during the digestive process.

As residual water treatment has low coverage, sludge management in Colombia is an area that has hardly started to grow, but will become an issue of great significance in the near future as the coverage improves. It is therefore important, through initial experiences in the generation and disposal of sludge, to study adequate practices for Colombia's social and economic conditions, monitoring the effects on the environment and on public health.

BIOSOLID CHARACTERISTICS

The biosolid characteristics produced by the treatment system El Salitre were compared with the EPA norms, and shown on Tables 1 and 2. It is important to notice that because of difficulties in counting enteric viruses, the use of bacteriophages as viral contamination indicators from fecal origin had been used. In this case viral presence was evaluated by the presence of somatic phages.

Table 1. Average concentration of heavy metals on biosolids produced at El Salitre compared with part 503 of the EPA norm 40 CFR

Parameter	Biosolids El Salitre (mg/kg)	Maximum Limits mg/Kg (EPA)
Arsenic	18.6	75
Cadmium	76	85
Copper	163.4	4300
Chromium	72.5	3000
Mercury	8	57
Nickel	42.9	420
Lead	87.5	840
Selenium	24.4	100
Zinc	1014.2	7500

Table 2. Average concentration of fecal contamination indicators in biosolids produced at El Salitre as compared with part 503 from the EPA norm.

Parameter	Units	Biosolids El Salitre	EPA Norm 40 CFR 503
Fecal coliforms	MPN/g CFU/g	9.31 x10^5	<1 x10^3 (Class A) <2x10^6(Class B)
Somatic phague	PFU/4 g TS	2.4x10^6	<1 (Class A)
Helminth Eggs	viable HE /4g TS	7.09	<1 (Class A)

CFU/g TS: Colony forming units per gram of total solids

PFU/g 4 TS: Plaque-forming units per four grams of total solids

HE/g 4 TS: Viable Helminth Eggs per four grams of total solids

The Environment and Territorial Development Ministry has been working on the norm on quality and disposition of biosolids. Currently there is a proposal for the norm, but in the meantime it has not been sanctioned. It is based on EPA norm (40 CFR Part 503) of 1999, which classifies sludge into classes A or B depending upon the microbiological quality (fecal coliforms, enteric viruses and Helminth eggs), as well as the concentration of heavy metals. Biosolids produced at El Salitre meet the standards regarding heavy metals concentration permissible to use without restriction, but for microbial quality it is classified as class B, because of its pathogen concentration.

BIOSOLID DISPOSITION

The biosolid applied at Doña Juana landfill is a sludge coming from El Salitre treatment system where it is stabilized by an anaerobic mesophilic system, and afterwards dehydrated and carried to the sanitary landfill. There, the arriving sludge is mixed with the soil in order to improve grass growing due to biosolid´s nutrients.

However, the biosolid boasts a high nutrient content, which cannot be ignored, because of its great potential in the improvement of soil for agricultural purposes. Therefore, to study its uses, the Empresa de Acueducto y Alcantarillado de Bogotá has begun a joint research alliance with the Pontificia Universidad Javeriana to learn about treatment and disposal of the produced biosolids.

In the case of agricultural uses, besides considering the EPA norm, it is important to take into account that the studies on which EPA norm is based, were conducted in environmental, social and economic conditions very different from developing countries such as Colombia. Bearing in mind the importance of avoiding damage to the environment or public health, it was decided to initiate a research process to determine whether it is necessary to apply the same restrictions as the EPA in this type of disposition.

One of the most outstanding experiences was on ryegrass cultures. Ryegrass was selected because Bogota is a savannah, where dairy products are produced and consequently needs high-quality grass. The research was carried out at the Experimental Station of the Javeriana University, where several plots were arranged using different mixtures of biosolid and soil. During 2 years of monitoring, data was collected including analyses of heavy metal concentration, soil agronomic and bromatologic characteristics, and grass production and soil and grass microbiological conditions.

Evaluation was carried out in a series of waterproofed plots separated by 1 m. The size of each plot was 9 x 6 m, for a total area of 54 m^2 per plot and a total area of 1,320 m^2. Five treatments were carried out, 3 of them with different mixtures of soil and biosolid and two controls; one with soil and other with biosolid. The treatment distribution was random, with 3 duplications by treatment.

The average results for pathogens found at the plots sowed with ryegrass pasture after 2 years of evaluation are shown on Table 3. For pathogenic bacteria, analysis of fecal coliforms were used as indicators. Helminth eggs were used as parasitic indicators and, because of difficulties in identifying enteric virus, somatic phages were used as indicators of viral contamination of fecal origin.

Samplings were carried out at the beginning, 6, 16 and 22 months. The results are the average of three duplicates per treatment.

Table 3. Average results of pathogens evaluated in plots cultured with ryegrass pasture

Treat-ment	September 2005			January-2006			May-2007			November 2007		
	FC	SP	HE	FC	SP	HE	FC	SP	HE	FC	SP	HE
T1	$4,0 \times 10^6$	1×10^6	1,5	$7,9 \times 10^4$	$4,0 \times 10^3$	9,5	$<1,7 \times 10^1$	$<7 \times 10^1$	1,5	$1,7 \times 10^1$	$1,2 \times 10^2$	1,1
T2	$3,2 \times 10^6$	1×10^5	0,8	$2,0 \times 10^4$	$4,0 \times 10^2$	11,1	$2,7 \times 10^2$	$<7 \times 10^1$	1,9	$2,1 \times 10^1$	$6,6 \times 10^1$	4,6
T3	$1,0 \times 10^6$	4×10^5	1,2	$2,0 \times 10^4$	$4,0 \times 10^2$	21,7	$<1,9 \times 10^1$	$<7 \times 10^1$	5,3	$1,7 \times 10^2$	$<8 \times 10^1$	12
SC	$3,6 \times 10^2$	6×10^2	<0.4	$1,3 \times 10^1$	$<5 \times 10^1$	<0,4	$<1,6 \times 10^1$	$1,1 \times 10^2$	0,6	$<1,6 \times 10^1$	$<6 \times 10^1$	4,0
BC	$7,9 \times 10^5$	2×10^5	<0.4	$1,6 \times 10^5$	$3,2 \times 10^3$	11,1	$2,4 \times 10^2$	$7,9 \times 10^2$	0,8	$<2,6 \times 10^1$	$<1 \times 10^2$	14

FC: Fecal Coliforms. Colony Forming Units/g dry weight
SP: Somatic Phages. Plaque Forming Units /4 g dry weight
HE: viable Helminth Eggs/4 g dry weight
T1: Treatment 3 parts soil + 1 part biosolid
T2: Treatment 2 parts soil + 1 part biosolid
T3: Treatment 1 part soil + 1 part biosolid
SC: Soil Control
BC: Biosolid Control

Table 3 shows that only after 2 years the values for fecal coliforms and somatic phages were near the expected ones for class A sludge, but not for helminth eggs. Heavy metals concentrations continue under the allowed values. The microbiological analysis regarding the pasture, show concentrations between 10^1 and 10^2 CFU/g in treatments and controls. Somatic phage concentrations and helminth eggs were under the detection limits.

Green forage productivity was very similar at each harvest. Productivity at the soil control was lower (8.4 – 14.4 Ton/Ha) as compared with the treatments having soil and biosolid mixtures (33.3 – 60.7 Ton/Ha). At the biosolid control productivity at the first harvest was lower as compared with the treatments (27 Ton/Ha) but with time it increased to 81.8 Ton/Ha.

Results show the potential use of biosolids in this type of cultures when there is controlled access of people and animals to the plots when the pathogen concentration is considered as sanitary risk.

EXPENSES RELATED TO TREATMENT AND MANAGEMENT OF BIOSOLIDS

- The average monthly expenditure for operation, administration and maintenance of the plant treatment is US$728.000
- Energy expenses for operation, administration and maintenance of the plant treatment is US$65.500
- The average monthly expenditure for biosolids disposal: US$10/ton to (SLDJ)
- The average monthly expenditure for biosolids transport US$11/ ton to (SLDJ)
- The resources for the operation, administration and maintenance of the plant come from the Secretaria Distrital de Hacienda by means of the LAW 715 and users do not pay.

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Cote d'Ivoire

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BACKGROUND

With an area of 322.500 km², Côte d'Ivoire is on Africa's west coast between the Equator and the Tropic of Cancer. Côte d'Ivoire is bordered on the north by Mali and Burkina Faso, on the west by Guinea and Liberia, on the east by Ghana and on the south by the Atlantic Ocean. This location explains the county's climactic variations. The country's population is estimated at about 20 million.

Figure 1. A map of Côte d'Ivoire's urban hydraulics as of 31 December 2006: Of all the cities in the country, only seven (7) have a sanitation development plan (Abidjan, Yamoussoukro, Bouake, Daloa, Daoukro, Gagnoa and San-Pedro).

Urbanization in Côte d'Ivoire is quite recent, but it has reached a relatively substantial level. According to the 1998 General Population and Housing Census (GPHC 98), urbanisation is now 42.49%. The number of cities with more than 100,000 inhabitants has increased from 5 to 8. Today, Cote d'Ivoire is administratively divided into 18 regions, 74 departments, 231 sub-prefectures, 197 municipalities and 8.500 villages.

SANITATION AND DRAINAGE SITUATION IN CÔTE D'IVOIRE

Poverty, formerly found mainly in rural areas, has now affected urban areas through rural migration. This new concentration of people has put pressure on social services, such as housing and sanitation.

In the current urban and rural development context, the Ministry of Construction Urban Development and Housing (MCUH), among others, is responsible for government policy relating to housing and urban and rural development, as well as basic sanitation.

Concerning the national Millennium Development Goals programme, needs for funding in wastewater collection and treatment and rainwater drainage are very important, amounting to more than 500 billion CFA francs.

To understand this situation, it is necessry to consider the past.

The national government's concerns regarding wastewater, rainwater drainage and collection of urban solid wastes go back to 1968-1970, following significant flooding and serious epidemics of contagious diseases that hit the whole country, particularly Abidjan – then a cosmopolitan city with more than 800 000 inhabitants from various countries and regions.

1973-1987

At that time, the Government undertook crucial actions, including:

- A request to UNDP and WHO for technical and financial assistance ; and
- The conduct of thorough studies.

These measures led to:

- Preparation of a sanitation development plan for Abidjan,
- Establishment of an institutional framework on sanitation and drainage development through creation of an operational technical structure, the Drainage and Sanitation Department (DDA 1975) attached to the SETU (Urban land development agency) and adoption of a law on the creation of the National Sanitation Fund (FNA) in 1976.

General directions

The general directions agreed on by the Government regarding sanitation, drainage and elimination of wastewaters in 1973, included:

- Elaboration and establishment by priority of basic sanitation and drainage infrastructures for Abidjan, to control sanitation and promote rapid expansion (annual urban growth rate was more than 10% at that time) ;
- Concentration of efforts on cities in the interior and on problems related to the drainage of rain waters, as waste waters evacuation does not present any major issue.

These directions fell under the objectives of the water and sanitation sector restructuring policy implemented by the Government between 1983 and 1991.

These objectives for the sanitation and drainage sub-sectors were aimed, among other things, at improving living standards, protecting the environment and properly managing infrastructure investments.

ABIDJAN

With the expansion of the city of Abidjan and the direct disposal of effluents into a lagoon, the need for a sanitation network emerged in the early 1970s.

Subsequent studies led to establishment of a development plan envisioning a separate system with two networks – one for drainage of rain water and one for collection of wastewater.

Concerning wastewater, the system retained is made up of a main structure called basic collector which is a 30 km long pipe network that starts in ABOBO should this be all caps? and extends south to the sea through a 1200 meter long emissary.

Funds invested and implementation mechanisms put in place sustained the development of the sanitation sector from 1976 to 1987 and these efforts attracted the World Bank's support in the achievement of specific actions.

During this period, out of the seven activities identified under Abidjan's sanitation development plan, only three were achieved, representing about 40% of the programme's targets.

The Government, represented by the ministry in charge of sanitation (Ministry of Construction, Urban Development and Housing) and SODECI, the country's water supply company, signed a leasing agreement for the use and maintenance of sanitation and drainage networks and infrastructures.

OTHER CITIES

From 1979 to 1980, series of sector-based sanitation and sewage studies were conducted in 51 other cities in Côte d'Ivoire. These studies helped to build a data base leading to the development of a so-called emergency programme for these cities.

The achievements of this programme can be essentially described as a few attempts at constructing drainage facilities.

1987 to 1999

At the national level, this progress in the sanitation and drainage sector initiated in the 70s was ended suddenly in December 1987 with the dissolution of SETU/DDA and the National Sanitation Fund.

Infrastructure development in this sector since then has not been anything worth noting and existing structures began to deteriorate at a frightening rate as a result of the changing of the leasing agreement into a services provision agreement.

Today, only 4 cities in Côte d'Ivoire have a sanitation development plan: Abidjan, Bouake, Yamoussoukro and Daoukro.

1999 to 2007

The number of cities having individual sanitation development plans has increased from 4 to 7 because of sanitation studies conducted in the cities of Daloa, Gagnoa and San-Pedro in 2002 through a grant from the African Development Fund of the AfDB.

Strategic actions undertaken resulted in the achievement of significant infrastructures (most infrastructures are found in Abidjan, with more than 2000 km networks and 51 plants).

Côte d'Ivoire so far has neither developed nor adopted a national sanitation policy as suggested by the former DDA in the 70s, nor has it developed a framework paper on hygiene and sanitation. The MCUH is striving to fill up this gap through the achievement of sustainable actions in the sector.

Except for Daoukro, actions and implementation programmes identified in almost all the sanitation development plans, were not executed. This is mainly due to sanctions imposed on Côte d'Ivoire, measures resulting from the socio-political and military situation.

RATE OF INFRASTRUCTURE COVERAGE

In urban areas: Barely 49% of all households (including Abidjan), have access to adequate sanitation facilities, and most investments so far have focussed on Abidjan.

- In Abidjan, continuous degradation of the lagoon's surroundings is not only a result of discharge into the lagoon of secondary and tertiary wastewaters collection networks and to the illegal wastewater connection to rainwater networks, but is also especially caused by transportation of solid wastes discharged in the network or carried away in runoff because of a lack of an efficient domestic waste collection system.

- Moreover, the lack of concrete channels for many low areas creates regressive erosion, which is often the cause of the silting up of bays. In addition, lack of development in the dissipation ponds causes floods during rainy seasons.
- Regarding wastewater, apart from the city of Yamoussoukro, which has a collective network system serving large schools and the teachers' residences, and that of San-Pedro, which has an embryonic non-functional collective network at several places, other cities resort to autonomous sanitation systems. They consist of a septic tank or often-inadequate pit latrines.

In rural areas: Forty-five percent of households are covered, but 36% of them have basic facilities, compared to 9% using adequate systems.

- The rural area in Côte d'Ivoire, housing more than 50% of the population of the country, has benefitted from considerable water supply infrastructure through the Government's policy under the National Village Hydraulic Programme (PNHV).
- This programme began in 1974, with the main objective of providing 15 to 20 litres of drinking water a day per inhabitant. It now covers more than 50% of the country's villages. However, preconditions for maintenance and improvement of villagers' health are frequently not met. Thus, the existence of areas where endemic diseases (gastro-enteritis, diarrhoea, poliomyelitis, dracunculosis, etc.) and recurrent cholera epidemics are widespread despite drinking water facilities.
- This situation is generally caused by lack of sanitation and the lack of hygienic practices. This issue is even more appalling as these behaviours and practices often reflect some traditions and beliefs (defecation in the environment, inadequate supply of drinking water during dry seasons).
- Demographic growth affects collective facilities and, correlatively, the need for financial investments that is becoming very important.
- One of the Ministry of Construction, Urban Development and Housing's missions is to promote and implement appropriate sanitation technologies, and help to find user-friendly alternative solutions that are easy to realise and accessible to all households.
- It is necessary to note that the 9% coverage rate of adequate systems was achieved using aid from third-party countries or international organisations under specific programmes. However, the MCUH intends, with the support of development partners interested in the sanitation sector in Côte d'Ivoire, to undertake a sector-based study on the urban and rural sanitation strategy over the whole country. This study could help identify the real national coverage rate.

NEW ARRANGEMENTS

The Ministry of Construction, Urban Development and Housing organised a seminar held 14-15 December 2006 on financing sanitation and drainage sectors under the courtesy of the Prime Minister. Important recommendations were made including:

- consolidation of the institutional framework through the creation of a functional technical structure to monitor activities of the sector,
- institutionalisation of a Fund called « National Sanitation and Sewage Fund » (FNAD),
- extension of sanitation charges to major cities in the country.

With virtually no development in the sub-sector, strategies and objectives defined for 2007-2015 include the following:

Development plan on sanitation and sewage

The Government will promote development plans on sanitation and sewage in cities in the interior to facilitate a rational programming of different actions.

Wastewaters

Regarding wastewater treatment in most cities, the Government will promote the set-up of collective networks through the construction of purification plants.

Disposal of excreta

On the elimination of excreta in most villages, the Government will encourage the development of individual autonomous sanitation or the construction of improved pit latrines adapted to local habits.

Drainage of rain water

The Government will mobilise funds to promote rain water drainage as well as the creation of a favourable environment for such investments.

The Government will also support the training of technical agents in the sanitation sector.

INVESTMENTS

In regional capitals, the Government will encourage the intervention of private operators through concessions that would promote necessary investments.

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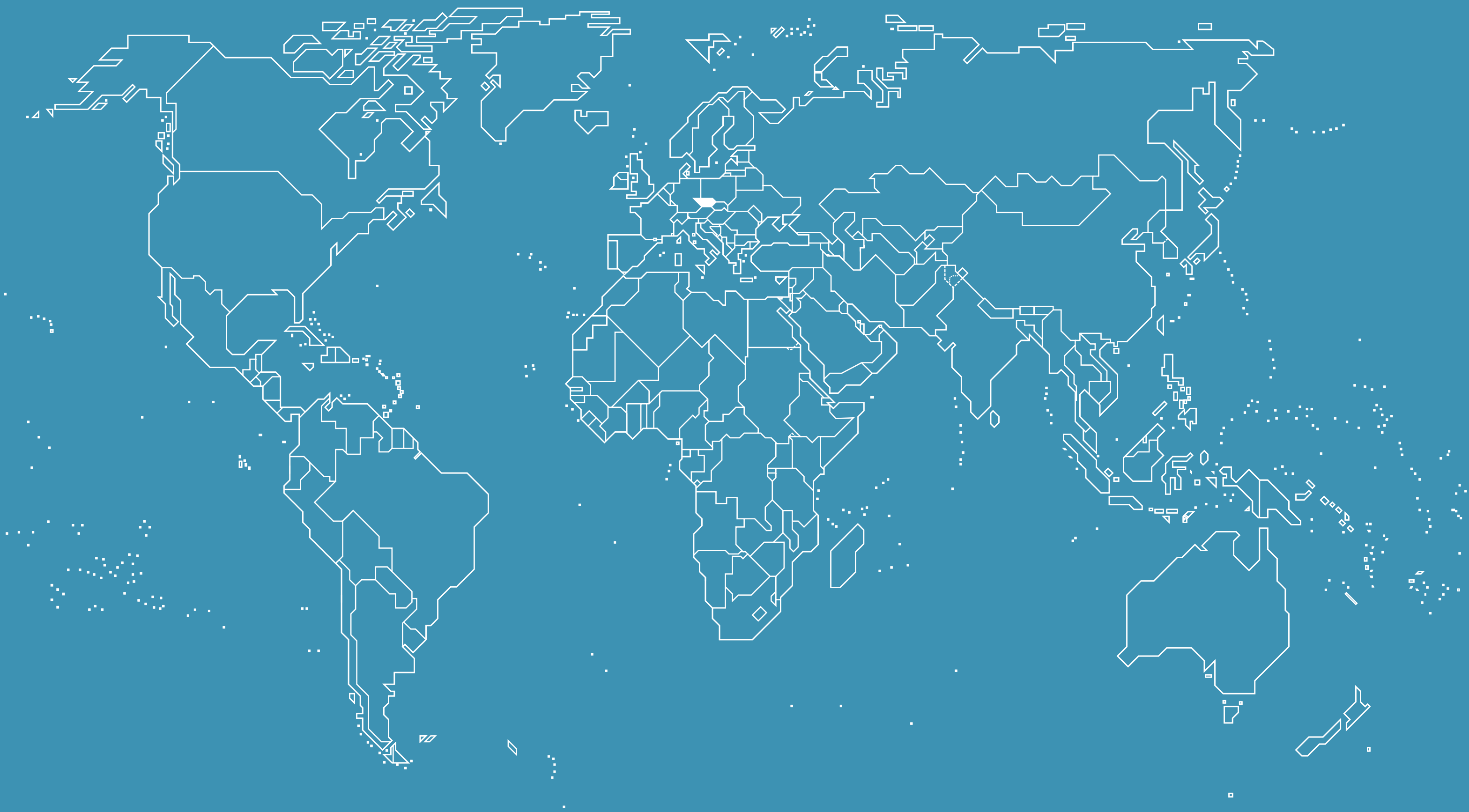


Czech Republic

Author: Pavel Jenicek

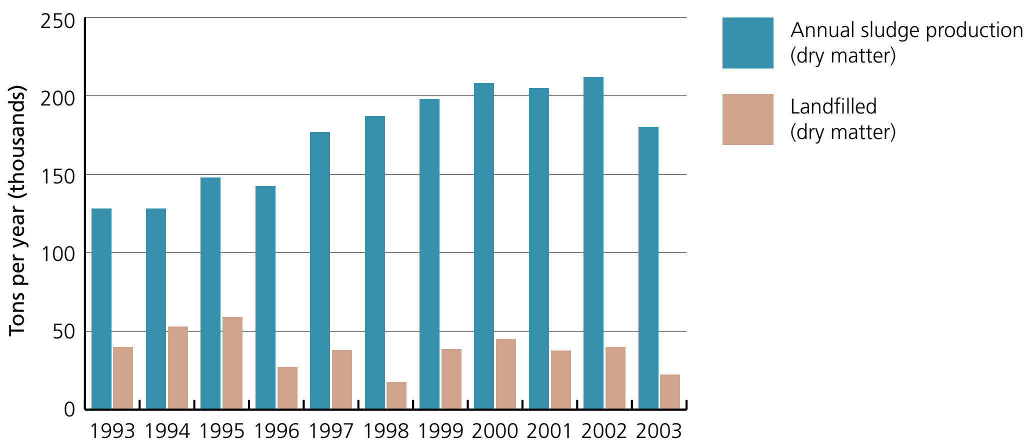
Czech Republic

BACKGROUND

In the Czech Republic there are almost 2000 municipal wastewater treatment plants in operation, which produce about 200 000 t dry total solids per year. Most of the wastewater treatment plants are operated by such international companies as Veolia, Ondeo, Energie AG, etc. The Czech Republic joined European Union in 2002, and therefore it was obliged to harmonize environmental legislation with EU states. That is the reason for many quantitative and qualitative changes in the sludge management.

A significant characteristic of sludge management in the all regions of Central and Eastern Europe is its rapid evolution. In the new EU member countries in particular, the amount of wastewater treatment plants is growing fast and the increasing share of biological treatment is the reason for a higher sludge production. For example, as shown in Figure 1, sludge production increased by about 65 % within a decade in the Czech Republic, while in the same time the amount of sludge disposed of in landfill showed a downward trend.

Figure 1. Development of sewage sludge production in the Czech Republic



Source: Michalova, 2004

The Czech Republic is the region's leader in the sludge management innovation. This can be illustrated by the full-scale use of mechanical sludge disintegration and the use of sludge lysate being produced during the disintegration or by rich experience with thermophilic anaerobic digestion. For example, the Prague wastewater treatment plant was able to double its biogas production over the last 10 years, from about 7,000,000 m³/year in 1993 to more than 16,000,000 m³/year in 2005. The mechanism for this was the enhancement of digestion capacity and sludge biodegradability via excess sludge thickening and disintegration carried out by lysate centrifuge and by the shift of operational temperature to the thermophilic range.

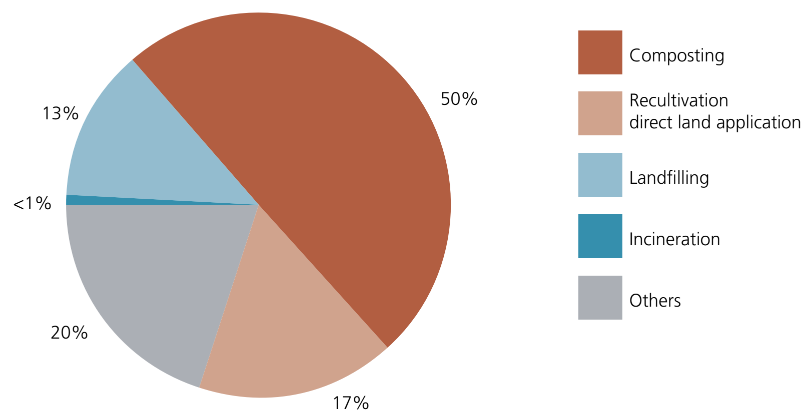
Due to legislative changes, the amount of landfilled sludge is decreasing – an important role is also played by high population density and low social acceptance of landfilling.

A slow increase in the market share of more expensive technologies, such as incineration or other thermal treatment methods, can be expected. However, this increase will probably be much slower than in Western Europe.

SELECTION OF DISPOSAL PRACTICE

Historically, the typical sludge disposal practice in the Czech Republic is agricultural land application. Direct land application has been decreasing in recent years, because of strict rules concerning the sludge quality, especially as regards heavy metal and pathogenic microorganism content. At the same time direct land application was substituted by composting. At present, the main part of sludge, about two-thirds, is used in agriculture. Sludge of insufficient quality is usually landfilled.

Figure 2. The methods of sludge disposal in the Czech Republic



Source: Michalova, 2004

ECONOMIC INFORMATION

The typical proportions of sewerage operation costs attributable to sludge are 11.7 %

- Capital and 56.8 % Operations & Maintenance (O&M):
- Costs of sludge disposal: 50 % of operational costs of wastewater treatment,
- Charge to customers for treating one cubic metre of sewage: 50 CZK (2 EUR)
- Cost of 1000 litres of diesel fuel: 3000 CZK, (1200 EUR)
- Cost of one kilowatt hour of electricity 4.35 CZK, (0.18 EUR)

AGRICULTURAL LAND APPLICATION

Agricultural use of sludge is strictly controlled by the law on solid wastes. The concentration of priority pollutants in sludge that can be used in agriculture is defined by government regulation – Table 1.

Table 1. Concentration limits of pollutants in sludge at agricultural land application

Parameter	Unit	Limit
As	$mg.kg^{-1}$	30
Cd	$mg.kg^{-1}$	5
Cr	$mg.kg^{-1}$	200
Cu	$mg.kg^{-1}$	500
Ni	$mg.kg^{-1}$	100
Pb	$mg.kg^{-1}$	200
Hg	$mg.kg^{-1}$	4
Zn	$mg.kg^{-1}$	2500
AOX	$mg.kg^{-1}$	500
PCB(Σ 6congeners)	$mg.kg^{-1}$	0,6

Defined are also limits of indicator microorganisms (thermotolerant coliform bacteria, enterococcus, *Salmonella sp.*) Table 2.

Table 2. The permitted amount of microorganisms in sludge at agricultural land application

Parameter	Unit	Class A	Class B
thermotolerant coliform bacteria	CTU/g DS (colony forming unit per gram of dry solids)	< 103	103-106
enterococcus		< 103	103-106
Salmonella sp.		negative	-

In some regions of the Czech Republic there was established a system of sludge supervisory service, which coordinates cooperation between sludge producers and farmers, and offers the optimal sludge distribution plan with respect to composition of soil and agricultural practice. The service also evaluates the influence of sludge on soil quality and increases the confidence of farmers.

LANDFILL

The amount of sludge that is landfilled in the Czech Republic has decreased during the last decade to half (see Figure 1) and now only about 10-15 % of sludge is landfilled, and usually it is sludge that contains high concentration of pollutants

INCINERATION

A negligible amount of sludge is incinerated in the Czech Republic, because incineration is among the most expensive methods of sludge disposal. At present, only one municipal wastewater treatment plant owns such technology. The incineration of sludge by cement factory furnace is also applied here. In the future an increase of sludge incineration can be expected, but its share will be probably slight.

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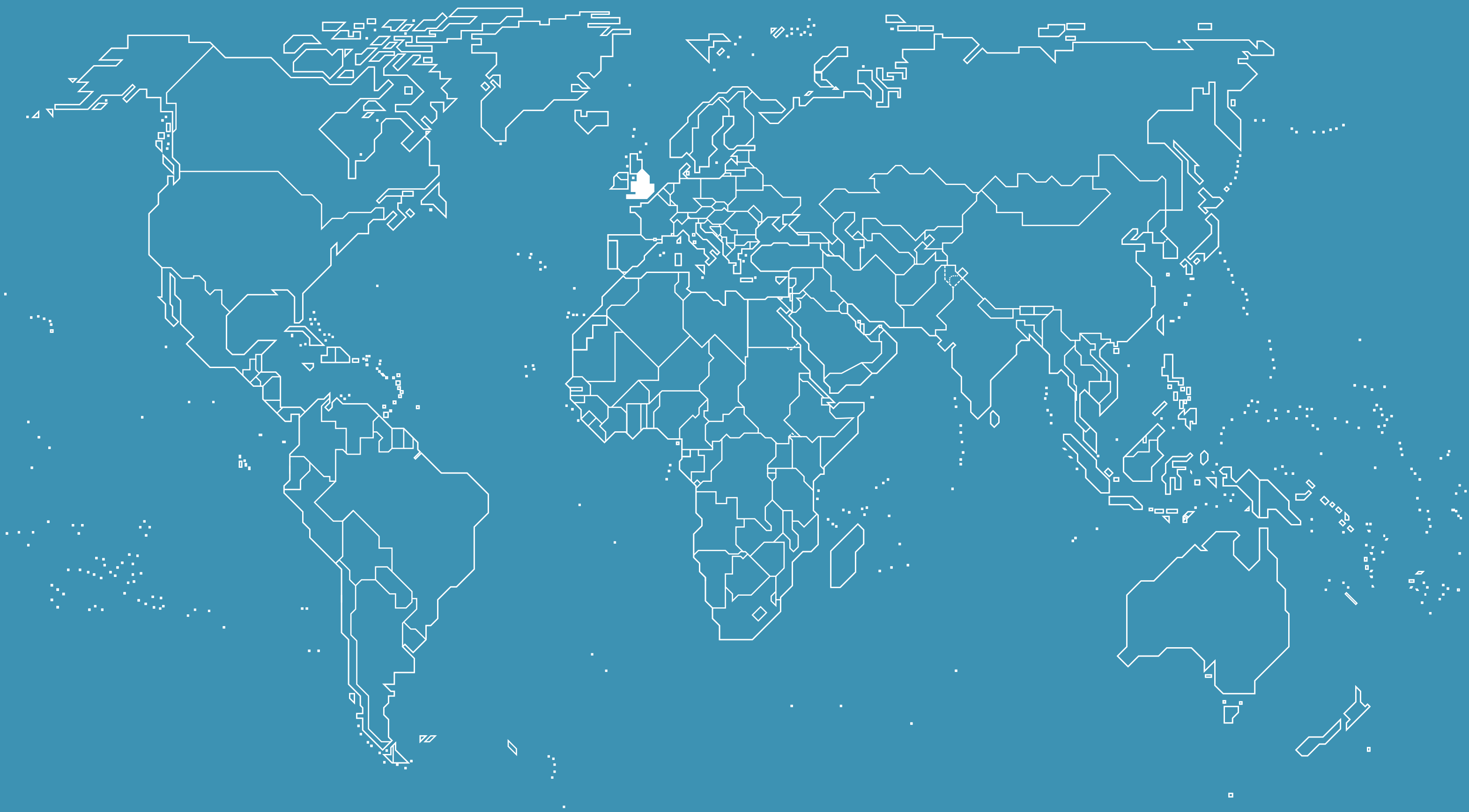

England and Wales

Author: Peter Matthews

England and Wales

INTRODUCTION

Nine waste-water companies serve regions of England, one serves Wales and one Government-owned company serves Northern Ireland; Scotland is served by a public utility. All own and operate the sewage treatment and sewerage assets, although some operations may be contracted out. They also provide water supplies.

The same principles apply throughout the UK but the Chapter is focussed on England and Wales and is exemplified by information from English regional Companies. The Companies charge customers directly for services on a full cost-recovery basis. The performances, expenditures and returns on assets of the Companies are regulated by a national economic regulator – the Water Services Regulation Authority (known as OFWAT). Environmental regulation, including the permitting of prescribed activities, is the responsibility of the Environment Agency, EA. The Government Department responsible for all these matters is that for the Environment, Food and Rural Affairs – DEFRA.

A great deal of the national legislation regulating sewage and sludge management implements relevant EU Directives. This is achieved by the issue of specifically focussed Regulations in England and Wales made under the Environment Protection Act of 1990 and the Environment Act of 1995

SELECTION OF DISPOSAL PRACTICES

The benchmark sludge/biosolids would be managed as part of regional operations. The UK produces 1.5Mdt sewage sludge per annum for use and disposal, and the management options for this are given in Table 1.

The selection of sludge management practice is based on an economic appraisal of available options. The long-term costs of meeting environmental protection criteria, transporting the sludge and meeting practicable operational needs are calculated and the least-cost option selected consistent with meeting legal requirements and corporate environmental policy. Computer models may be used; several Companies have used WISDOM (Water Industry Sludge Disposal Optimisation Model) developed by the Water Research Centre. This approach is known in the UK as the Best Practicable Environmental Option, which is described in documents produced by HMSO, the Water Research Centre and the Environment Agency. Sustainability now plays a key role. BPEO was termed by the Royal Commission on Environmental

Pollution, as the option that provided the most benefits, or least damage, to the environment as a whole, at acceptable cost, in the long term as well as the short term.

Table 1. Sludge production and disposal for 2005

Water Company	Total Sludge dt	% Used on Nonagricultural Land	% Used in Agriculture on Land	% Disposed to Landfill	% Incineration and other thermal destruction inc EFW processes	% Other
Anglian	1640000	4.6	94.0	1.4	0.0	0
Northumbrian	66000	5.8	67.1	1.3	0.0	25.8
Severn Trent	210000	10.6	73.9	0.0	15.5	0.0
Southern	105000	0.0	98.9	1.1	0.0	0.0
South West	57000	0.0	99.3	0.7	0.0	0.0
Thames	264000	9.1	60.3	0.0	30.5	0.0
United Utilities	22800	17.2	64.9	0.1	17.8	0.0
Welsh	72000	4.5	95.0	0.5	0.0	0.0
Wessex	68000	18.6	81.4	0.0	0.0	0.0
Yorkshire	135000	6.3	20.1	1.0	65.6	4.6
England and Wales	1369000	7.8	71	0.5	17.7	2.0
UK	1509000	5.2	67	1.5	19.5	1.8

Landfill, which was always the less preferable option, is now used less due to increasing restrictions, lack of site availability and costs. So in simple terms, at present, sludges may be treated and used on land or vastly reduced in volume by thermal destruction processes, principally incineration, with consequent disposal of ash.

The option most used in England and Wales is recycling to agricultural land as a fertiliser and soil conditioner and this is the focus of this Chapter. The term used for treated sludge used in accordance with legislation is 'biosolids'. However incineration is often used for sludges produced from large conurbations

Sludges are produced from a very wide variety of treatment works sizes ranging from those serving a few people to those serving millions of people. The water companies run integrated operations, in which sludge treatment centres play a crucial role. When treated sludges are used as biosolids in agriculture, as for other management methods, they are likely to be mixed rather than from a single source. The benchmark works is, therefore, likely to act as such a centre. The sludge values specified for the benchmark sludge are not unreasonable for the purpose of exemplifying UK practices, although in many instances the products available are considerably better quality

The companies are also responsible for the control and regulation of industrial effluents discharged into public sewers; this is essential in ensuring effective sludge treatment and recycling to land. They have extensive laboratory and scientific facilities and do their own monitoring.

ECONOMIC INFORMATION

- Typical proportion of sewage operation costs attributable to sludge: 20 % capital, 15% running costs
- Range of charges to customers of treatment 1m³ of sewage : Range £0.49 – 2.56 + £11-77 per year standing charge
- 100 litres of diesel fuel : about £110 at public pumps
- one kilowatt hour electricity : about £0.10 – 0.20, depending on consumption

LANDFILL OPTION

If the benchmark sludge were to be so disposed, the conditions of the operation would be governed for a particular site by the conditions of a pollution prevention and control permit issued by the Environment Agency under regulations, made pursuant to the Environment Protection Act 1990, which implemented the EU directives for Waste, Landfill and Integrated Pollution Prevention and Control. The permit defines the conditions necessary to avoid immediate and long-term nuisance and pollution and site after care. The most likely scenario is for co-disposal with domestic waste; dewatered sludge would be required. Liquid sludges can no longer be disposed of into landfill sites. The extent of dewatering and stabilisation and likely length of operation would vary from site to site. The European Union restricted land filling in general under the 1999 Landfill Directive, which underpins national and local rules. The transport of the sludge is also regulated.

INCINERATION OPTION

If the benchmark sludge were to be incinerated, the incinerator would have to be regulated by the Environment Agency by means of pollution prevention and control permit, again made under Regulations, pursuant to the Environmental Protection Act 1990, which implement the IPPC Directive (1996) and Waste Incineration Directive (2000). The permit would pay particular attention to air emissions. Disposal of ash would almost certainly be to landfill, the control of which has been described. The Environment Agency has issued guidance on what is expected as best available technology. The location of an incinerator will be subject to Environmental Impact Assessment under national laws which also implement European Union legislation. The transport of the sludge would be regulated. The sludge would be dewatered and the most likely technology being fluidised bed – but the achievement of emission standards would require extensive additional processes. Details can be found on the Environment Agency's website www.environment-agency.gov.uk.

This would not be a favoured option for the benchmark sludge unless it were to be transported to a very large treatment centre employing the process.

Whilst there continues to interest in other thermal processes, such as pyrolysis and gasification, these would not be selected for the benchmark sludge, unless it was transported to a large treatment centre employing the processes.

LAND USE OPTION

Agricultural utilisation

This is the most favoured option, accounting for a high proportion of sludge produced (see Table 1). The agricultural use of biosolids is provided within the companies' regions by locally focussed services. The regional policies extend and apply national policy requirements. The regional policies extend and apply national policy requirements. These incorporate the European Union Sludge Use Directive of 1986. The 1989 Sludge (Use in agriculture) Regulations apply the precise requirements of the Directive. In addition, a Code of Practice defines a number of aspects left to national discretion and extends the constraints according to national requirements; this was modified in 1993. The principal criteria are given in Tables 3-8 Compliance with the Code is not absolutely mandatory but if the Code is not complied with and an environmental problem occurs, the offender is liable under the Environmental Protection Act 1990. Provided that these rules are followed no permit to use the biosolids is needed.

In the late 1990's the food retail industry became concerned about perceptions regarding the quality of food grown on land fertilised by biosolids. As a result, an agreement was reached between the British Retail Consortium, Water UK (which represents the UK Water Utilities), and ADAS (the Agricultural Development and Advisory Service), with the support of the Environment Agency. A Safe Sludge Matrix was developed as a practical addition to the Code of Practice. The Matrix requires the sludge to be treated by a quality-assured system to reduce pathogen load. Whilst this has not been incorporated yet formally into law, this approach has been adopted by all Companies. It is recognised by OFWAT for the purposes of regulating investment and expenditure, by the Environment Agency for the purposes of environmental protection and, by the DEFRA, particularly in relation to subsidy payments under the EU Common Agricultural Policy. Under this, the subsidies to farmers have shifted from food production per se to environmental and animal health stewardship. The changes are given in Table 8 but more information on particular agricultural uses may be found on the website for the Sustainable Organic Resources Partnership (www.sorp.org.uk). The Matrix contains the principal set of criteria. There is a case for not including Tables 5-7, but they have been included, as they are still the legal baseline and to provide a useful comparison to current practice. Guidance on the definitions of acceptable treatment is given in Table 3 and most are still accepted, subject to meeting more demanding performance criteria. New processes are being developed to meet the criteria.

Other requirements relate to legislation and guidance regarding transport and storage, public health, fertiliser use, particularly nitrate in accordance with Regulations for Nitrate Vulnerable Zones applying the EU Nitrate Directive (1991) and the control of plant and animal diseases.

Use of biosolids on agricultural land is audited by the EA; the Companies must maintain registers detailing types and quantities of sludge produced, where it has been recycled and quantities of sludge produced, where it has been used and the quality of the biosolids and the land.

Biosolids use is encouraged in England and Wales as a contribution to the environment in aiding used water management and by recycling valuable nutrients and organic matter. It is recognised by the Government as the BPEO in most circumstances. The philosophy is that caution and control are needed and so limits are essential to constrain operational practice. This differs from other philosophies, such as that which says that if there might be a problem do not do it – often described as the precautionary principle.

Company product and service schemes are supported by information and monitoring and are advertised widely. The objective is to work with farmers in best agronomic practice. Specialist contractors or farmers or the companies themselves may deliver and apply biosolids to farms. In some cases storage on farms is provided to balance the differences between supply and demand. The aim is to have a long-term relationship with farmers.

The key features of national policy for agricultural use are described in Tables 3-8. These are extended in the companies' practical manuals of good practice to reflect local circumstances. The prime drivers in treatment and in the restrictions on use are prevention of pollution, and of the spread of diseases. However, if digestion is used, the value of the energy created from the methane in the sludge gas is becoming increasingly important.

In the Code of Practice, compliance with the requirements for the treatment criteria and with the controls on the application and farming practices assured protection. But the Safe Sludge Matrix goes further in requiring a demonstration of process effectiveness by attaining specified levels of pathogen reduction using E.Coli as an indicator (and Salmonellae for the most demanding requirements). This is not a product specification and the difference between the requirements for that and what is in the Matrix lies in the nature of the monitoring programmes.

Research and epidemiological study during formulation of the original Code of Practice showed that safe practice with Salmonellae in particular would also prevent risks from other organisms such as Taenia. Local agronomic and industrial circumstances may require especial care, for instance potato cyst nematode in Anglia (Eastern England) – due to high potato production. The predominant agriculture in Regions varies, but more biosolids are used on arable land.

A common method of treating sludge at present is anaerobic digestion meeting the terms of the Matrix. After a period of doubt in the 1990's about the future of anaerobic digestion, the process now has a secure central place in biosolids strategies and design and operation of plants has developed significantly. The process has been extended to higher levels of efficacy and effectiveness to meet the terms of the Matrix by the use of additional steps such as enzymic hydrolysis. It has the advantage of also improving product quality (i.e. producing ammonia, improving consistency, and reducing smell), producing gas and reducing volume. A number of other techniques are developing – for example research into other processes, such as vermiculture, continues.

Rates of application are limited to avoid unacceptable accumulation of metals in soil. The 1986 EC Directive has metal loading rates or sludge concentrations to achieve this. The UK selected the former.

In the UK there are extra limits beyond those defined by the EU Directive (see tables). As a guide, typical sludge concentrations taken from national surveys done some years ago and soil background concentrations are given below for planning purposes. Sludge values could well be lower in general now.

Table 2. Typical soil background and historic sludge values for elements not defined by the EU directive

	Soil mg / kg	Sludge mg / kg
Chromium	15	50
Molybdenum	15	1
Selenium	0.2	0.3
Arsenic	10	3
Fluoride	60	100

For the purposes of this contribution, it is assumed that there are no other chemicals present in the benchmark sludge requiring special attention. These would be restricted by industrial effluent control. There are no limits for dioxins and furans or PCBs, for instance.

The pH values of soils do have the sort of range envisaged in UK Regulations but use of 6.5 as envisaged in the specification for the benchmark soil is reasonable to exemplify the UK position; a soil density of about 1.3 w/v is reasonable.

Use on grazing land

If the benchmark biosolids are used on grazing land, a common method would be by injection of the digested biosolids or spread on the surface. This may involve the use of tankers able to transport biosolids from the works and apply them to the land. However, it often involves delivery to storage facilities on farms and then the use of more specialised equipment to spread or inject. This storage varies from hours to months depending on local circumstances and is helpful in balancing supply and demand.

The quality of the benchmark sludge would not be an impediment to any use, and it would probably be applied annually if possible in the early spring at the rate of about 5 dry tonnes/ha. The primary interest would be for the nitrogen content At this rate, the benchmark typical site could be used for about 80 years and this would be limited by copper, (based on the regulation 7.5cm sample depth but it is possible that for practical purposes sampling may be conducted at the standard 15 cms. as per arable soils).

The animals most likely to graze would be cattle and sheep.

The farmers will often want quick response from the nitrogen as well as the benefits of the phosphate and hence would prefer the biosolids to be digested. If the farm is in a statutory nitrate-vulnerable zone, and a great deal of the country is so regulated, (applying the requirements of a EU Directive), the annual biosolids application will be restricted to 250 kg N/ha (of the order of 7 dry tonnes/ha of the treated benchmark biosolids)

Use on arable land

This is practiced commonly in many Regions. A whole variety of treatment methods might be used depending on the local treatment facilities. There would be no set requirement and many factors would be taken into account. However, anaerobic digestion is practiced commonly. The biosolids may also be dewatered. This would almost certainly be by centrifuge or belt press. The same management controls over delivery and storage on farms as described for grassland would apply to arable land

The application rate would depend on the crops, which would probably be a cereal, but on a local basis could be maize, rape, or sugar beet, (uses for growing potatoes and other root vegetable etc have become much less frequent in recent years). A typical application rate would be 6-8 dry tonnes/ha/year. The biosolids may also be dewatered if the soil type is heavy and likely to become waterlogged or if the farms are a long distance from the works e.g. beyond 10 km.

The Companies would work closely with the farmer in terms of the nutrients and organic matter supplied. Farmers are keen to know about nitrogen availability and contribution to the soil phosphate reservoir. Nutrient availability varies with treatment method – for example anaerobic digestion converts the slow-release organic nitrogen into quick-release ammoniacal nitrogen. Dewatering removes soluble nitrogen and hence removes a lot of readily available nitrogen from digested sludge nitrogen. Dewatered sludge may be applied at higher rates, less frequently (but the restrictions of nitrate-vulnerable zones of 250kgN/ha would tend to restrict this). The supply of types of biosolids will depend on local availability and obviously a regional works cannot meet the individual needs of every farmer.

Normal plough depth in arable soil, particularly in the lowlands is 20 cms and hence the soil is normally monitored up to a depth of 15 cms (to avoid edge effects). On this basis, the benchmark biosolids applied at 5dtonnes/ha/yr could be used for about 130 years on the typical soil and this would be limited by copper and zinc accumulation. If the site were deep-ploughed to 25 cms, the site life could be extended to about 160 years. Higher rates would reduce the site life.

There would be a variety of practices for the supply of biosolids to farmers according to local circumstances and this may involve storage on farms. Where liquid biosolids are supplied this would probably mean increasing storage in lagoons and injection to reduce odours and improve the supply of nutrients.

Domestic use of biosolids

In the past, small qualities of biosolids have been supplied to the domestic and horticultural market. The practice has not been widely encouraged for the domestic market due to the difficulties of effecting realistic controls over application and the disproportionate costs. However all the time that staple crop agriculture provided a more stable and cheaper option, there was not a big push to develop horticultural services.

One opportunity to supply a product would be a compost, which incorporated sludge with other materials. Investigation of this continues but, so far, products including a straw-based compost have not proved to be an attractive replacement or cost-effective. If such products are supplied, there is a move towards the much tighter standards produced by the British Standards Institution, known as PAS 100, for composts, and details can be found on the SORP website

It is very unlikely that anything more than a small fraction of the benchmark sludge would be managed in this way.

Use in forest or woodland

Only a modest amount of sludge is used as biosolids in this way If the benchmark sludge were to be used in this way, practices would be governed by a Water Research Centre/Forestry Commission Code of Practice. This employs the same soil criteria as those used for agriculture on the basis that this protects the trees and that the soil could be used for agriculture in future. Untreated sludge is no longer used for any part of the forestry cycle.

The biosolids could be applied as a liquid by spray gun as a liquid or as dewatered cake by solid material spreader depending on the nature of the plantation and soil. This use is expanding slowly, it might well be possible to supply some of the biosolids in future for the growth of conifers, such as spruce.

In recent times biosolids applied at the rate of up to 6 tonnes ds/ha have found to sustain the rapid growth of tree stocks such as willow and poplar. The harvested wood can be used for a number of purposes, including use as a fuel source. The use of untreated sludge is permitted. Sludge and biosolids are also very good for the growth of Miscanthus sp. It would not be beyond practical reason to supply some of the benchmark sludge to short rotation coppice plantations. The same soil criteria would apply.

Use on conservation land or recreational land

It is unlikely that use in this way would ever constitute more than a small fraction of the disposal of the model sludge. This market might be bigger than that at present if the biosolids were composted or dried and pelletised.

The soil criteria for agricultural land apply, and it is likely that only fully treated biosolids would be used, particularly on recreational land.

Use for land reclamation

Whilst this may not yet provide a significant outlet, there is increasing use of biosolids in this way. However, these tend to be opportunistic due to timing and location. Examples of such practices include, fertilising the soil, capping land fill sites and creation of woodland on brownfield sites. It is likely to be digested sludge – probably dewatered, probably by centrifuge or filter belt press.

PRODUCTION OF DERIVATIVE MATERIALS

None are produced or would be produced from works of the benchmark size.

SOME THOUGHTS FOR THE FUTURE

The two main options will continue to be recycling and thermal treatment. The issues energy consumption/production and carbon footprint will become important in assessing the sustainability of operations. DEFRA published its Waste Strategy in 2007 and this encourages recycling. The independent SORP was established in 2003 to encourage the safe, sustainable, welcome, and trusted recycling of all organic resources in an integrated fashion and will continue to work alongside Government departments including funded programmes such as the Waste Recycling Action Programme.

The EU is in the process of revising the Waste Framework Directive, which could have consequences for sludge management. It would desirable if treated sludges used properly as biosolids could be no longer classified as a waste. The UK and EU are in the process of reviewing sludge use legislation. The UK Government has proposed the incorporation of the Safe Sludge Matrix into Regulations and could incorporate further changes to reflect any developments of knowledge and attitudes.

If implemented, the Regulations would make many of the restrictions explicitly mandatory, rather than placed in a Code context. So the changes to the Regulations would be:

- Use of untreated sludge would be banned
- Treatment will be in accordance with definitions of conventional treatment and enhanced treatment
- Conventional treatment is 99% (2 log) reduction of E. Coli and an MAC of 100000 per gram DS
- Enhanced treatment is 99.9999% (6 log) reduction of E. Coli and an MAC of 1000 per gram DS and an absence of Salmonellae sp
- Keep Registers of sludge quality and treatment operations
- Allow access to the EA for audit
- Ban the use of conventional sludge on grassland unless it is incorporated
- Restrict access for harvesting or grazing for conventional sludge to 12-month intervals for field vegetables and 30 months for vegetables eaten raw
- Max limit for lead lowered to 200mg/kgDS
- Max limit for zinc in soils pH 5.5-7.0 would be 200mg/kgDS and for pH values above 7 with a calcium carbonate content more than 5% would be 300mg/kgDS
- Require notification of filed operations by disposer to the EA
- Extend registered record-keeping of farms, etc.

- Require that more information be given to farmers, require that producers make an annual return to the EA
- Allow the EA to charge for the costs of extended regulation

In addition the Code would be extended to include

- Additional chemical monitoring and record-keeping
- Requirements regarding control of trade effluents
- Explanation of hazard critical control point approaches to sludge treatment
- Pre-notification of application operations to local municipal authority Environmental Health Officers
- Give advice on operational best practice
- Give advice on the beneficial effects on soil
- Advise on the use of a Model Sludge Agreement to be used between farmers and disposers
- Guidance on non-food crops

However as yet there are no firm indications as to when the law will be changed. Nevertheless the Companies are incorporating the principles in their operations. There is a clear awareness of the issues of risk management and accredited quality assurance programmes and many schemes have been registered under ISO 14000 or 9000.

Table 3. Maximum permissible concentration of potentially toxic elements in soil after application of sewage sludge and maximum annual rates of addition. (UK)

PTE	Maximum permissible concentration of PTE in soil (mg kg dry solids) pH(1) 5.0<5.5	pH(1) 5.0<6.0	pH 6.0-7.0	pH(3) >7.0	Maximum permissible average annual rate of PTE additional over a 10 year period (kg/ha) (2)
Zinc	200	250	300	450	15
Copper	80	100	135	200	7.5
Nickel	50	60	75	110	3
For pH 5.0 and above					
Cadmium	3				0.5
Lead	300				15
Mercury	1				0.1
*Chromium	400				15
*Molybdenum (4)	4				0.2
*Selenium	3				0.15
*Arsenic	50				0.7
*Fluoride	500				20

** These parameters are not subject to the Provisions of Directive 86/278/EEC*

(1) For solids of pH in the ranges of 5.0<5.5 and 5.5<6.0 the permitted concentrations of zinc, copper, nickel and cadmium are provisional and will be reviewed when current research into their effects on certain crops and livestock is completed.

(2) The annual rate of application of PTE to any site shall be determined by averaging over the 10 year period ending with the year of calculation.

(3) The increased permissible PTE concentration in soils of pH greater than 7.0 applies only to soils containing more than 5% calcium carbonate.

(4) The accepted sale level of molybdenum in agricultural soils is 4mg/kg. However there are some areas in UK where, for geological reason, the natural concentration of this element in the soil exceeds the level. In such cases there may be no additional problems as a result of applying sludge, but this should not be done except in accordance with expert advice. This advice will take account of existing soil molybdenum levels and current arrangements to provide copper supplements to livestock.

Table 4. Maximum permissible concentration of potentially toxic elements in soil under grass after application of sewage sludge when samples taken to a depth of 7.5cm (UK)

	Maximum permissible concentration of PTE in soil (mg kg dry solids)			
PTE	**pH(1) 5.0<5.5**	**pH(1) 5.0<6.0**	**pH 6.0-7.0**	**pH(3) >7.0**
Zinc (1)	330	420	500	750
Copper (1)	130	170	225	330
Nickel (1)	80	100	125	180
For pH 5.0 and above				
Cadmium (2)	3/5			
Lead	300			
Mercury	1.5			
*Chromium	600			
*Molybdenum (4)	4			
*Selenium	5			
*Arsenic	50			
*Fluoride	500			

** These parameters are not subject to the Provisions of Directive 86/278/EEC*

(1) The permitted concentrations of these elements will be subject to review when current research into their effects on the quality of grassland is complete. Until then, in cases where there is doubt about the practicality of ploughing or otherwise cultivating grassland, no sludge applications which would cause these concentrations to exceed the permitted levels specified in Table 4 should be made except in accordance with specialist agricultural advice.

(2) The permitted concentration of cadmium will be subject to review when current research into its effect on grazing animals is completed. Until then, the concentration of this element maybe raised to the permitted upper limit of 5mg/kg as a result of sludge applications only under grass which is managed in rotation with arable crops and grown only for conservation. In all cases where grazing is permitted no sludge application which would cause the concentration of cadmium to exceed the lower limit of 3mf/kg shall be made.

(3) See Table 1, Note (3)

(4) See Table 1, Note (4)

Table 5. Examples of effective sludge treatment processes in the 1989 Code of Practice (UK)

Process	Description
Sludge Pasteurisation	Minimum of 20 mins at 70⁰C or minimum of 4 hours at 55⁰C (or appropriate intermediate conditions), followed in all cases by primary mesophilic anaerobic digestion.
Mesophilic anaerobic digestion	Mean retention period of at least 12 days primary digestion in temperature range of 35⁰C ±3⁰C or at least 30 days primary digestion in temperature range 25⁰C ±3⁰C followed in each case by a secondary stage which provides a mean retention period of at least 14 days.
Thermophilic Aerobic Digestion	Mean retention period of at least 7 days digestion. All sludge to be subject to a minimum of 55⁰C for a period of maturation adequate to ensure that the compost reaction process is substantially complete.
Composting (Windrows or Aerated Piles)	The compost must be maintained at 40⁰C at least 5 days and for 4 hours during this period at a minimum of 55⁰C within the body of the pile followed by a period of maturation adequate to ensure that the compost reaction process is substantially completed.
Lime Stabilisation of Liquid Sludge	Addition of lime to raise pH to greater than 12.0 and sufficient to ensure that the pH is not less than 12 for a minimum period of 2 hours. The sludge can then be used directly.
Liquid Storage (But no longer recognised as being effective)	Storage of retreated liquid sludge for a minimum period of 3 months.
Dewatering and Storage	Conditioning of untreated sludge with lime or other coagulants followed by dewatering and storage of the cake for a minimum period of 3 months. If sludge has been subject to primary mesophilic anaerobic digestion, storage to be for a minimum period of 14 days.

Table 6. Acceptable uses of treated sludge in agriculture in the 1989 Code of Practice (UK)

When applied to growing crops	When applied before planting crops
Cereals, Oil seed rape Grass (1) Turf (2a) Fruit Trees (2b)	Cereals, grass, fodder sugar beet, oil seed rape, etc. Fruit trees Soft fruit (2b) Vegetables (3) Potatoes (4) Nursery stock (5)

(1) No grazing or harvesting within 3 weeks of application.

(2) Not to be applied within (a) 3 months, (b) 10 months, (c) 6 months before harvest.

(3) Not to be applied within 10 months before harvest if crops are normally in direct contact with soil and may be eaten raw.

(4) Not to be applied to land used or to be used for cropping rotation that includes the following: (a) basic seed potatoes, (b) seed potatoes for export.

** Injection carried out in accordance with WRc publication FR008 1989, "Soil Injection of Sewage Sludge – A Manual of Good Practice (2nd Edition)"*

Table 7. Acceptable uses of treated sludge in agriculture in the 1989 Code of Practice (UK)

When applied to growing crops by injection	When cultivated or injected* into the soil before planting crops
Grass (1) Turf (2a)	Cereals, grass, fodder sugar beet, oil seed rape, etc. Fruit trees Soft fruit (3) Vegetables (3) Potatoes (3), (6)

(1) No grazing or harvesting within 3 weeks of application.

(2) Not to be applied within (a) 3 months, (b) 10 months, (c) 6 months before harvest.

(3) Not to be applied within 10 months before harvest if crops are normally in direct contact with soil and may be eaten raw.

(4) Not to be applied to land used or to be used for cropping rotation that includes the following: (a) basic seed potatoes, (b) seed potatoes for export.

** Injection carried out in accordance with WRc publication FR008 1989, "Soil Injection of Sewage Sludge – A Manual of Good Practice (2nd Edition)"*

Table 8. Safe sludge matrix – September 1998 (Last revised 2001)

Crop	Use of Untreated Product	Use of Conventionally Treated Product * e.g. digestion	Use of Enhanced Treated Product ** e.g. heat treated
Horticulture	Banned	Banned	As CoP (>10 Months before harvest
Fruit	Banned	Banned	As CoP (>10 Months before harvest)
Vegetable Crops inc salads in direct contact with soil and may be eaten raw	Banned	No application within 30 months of harvest of veg.	As CoP (>10 Months before harvest)
Other Vegetable Crops	Banned	No application within 12 months of harvest of veg.	As CoP (>10 Months before harvest)
Combinable and animal feed crops etc. Grain, Oilseeds, Sugar beet	Banned	As CoP	As CoP
Grass Harvested Silage	Banned	Deep injected or ploughed down only (3 week no harvest interval and no grazing in season of application)	As CoP (3 week no harvest interval)
Grass Grazed	Banned	No grazing in season of application	As CoP (3 week no grazing interval)

** As in current UK DoE Code of Good Practice but with the target of 99% reduction of pathogens as measured by E coli*

*** Target of 99.9999% reduction of pathogens as measured by E. coli and absence of salmonellae*

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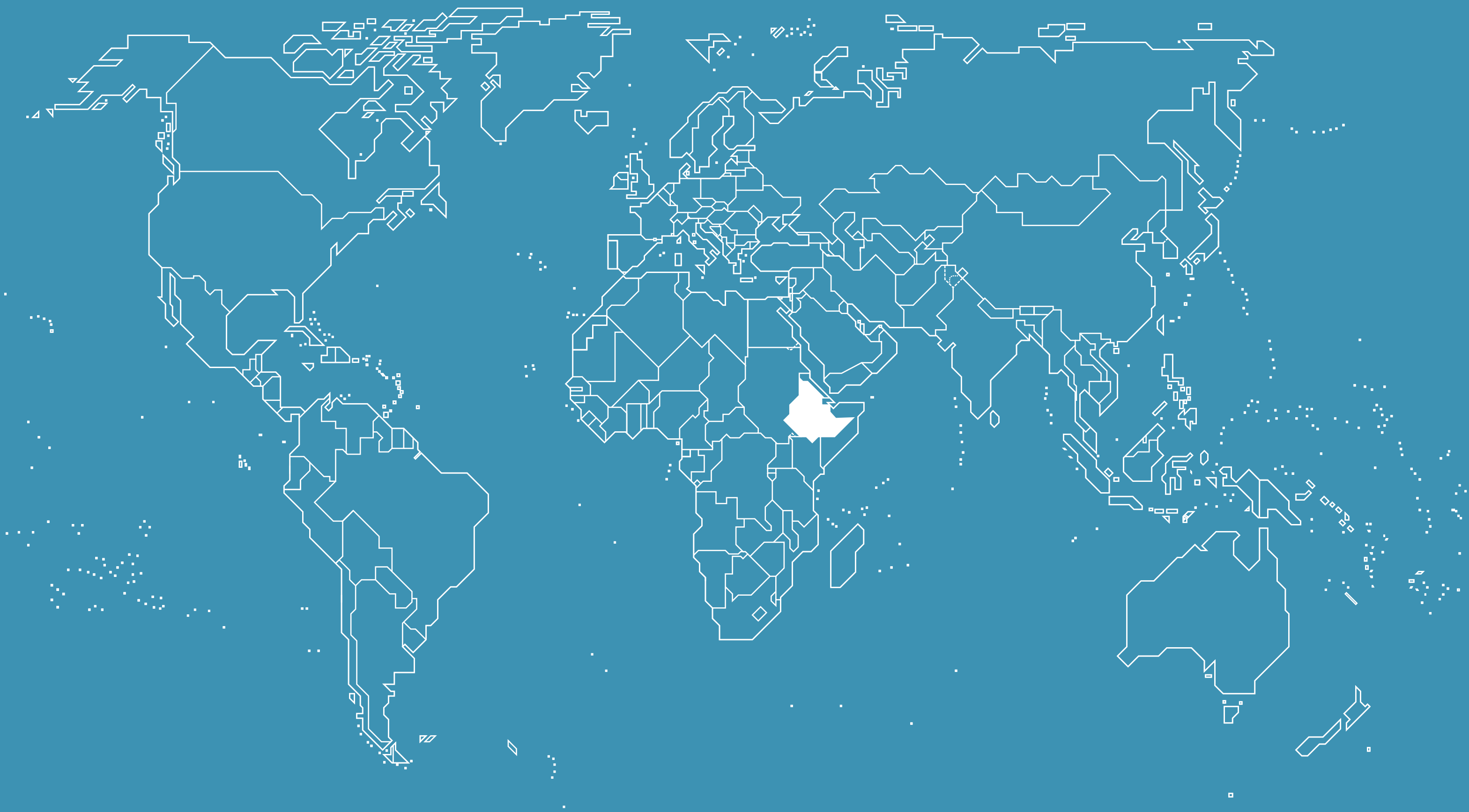


Ethiopia

Author: Tewelda Abdosh

Ethiopia

GENERAL INFORMATION OF HARAR REGARDING THE SLUDGE/FAECAL SLUDGE/SEPTIC WASTE/EXCREMENT WHICH IS PRODUCED IN THE CITY OF HARAR

Q1. How much of these materials are managed in your jurisdiction each year? How much additional material is not managed, is ignored, and is untreated and/or untracked? Please describe the population(s) served by the management of these materials.

The amount of solid wastes generated in the city in descending order are domestic wastes, commercial wastes (solid wastes from market areas, from various trade activities including butcheries, hotels, grain mills and the like, shops and other related activities), industrial wastes and hospital wastes. The Chat trimmings that have been generated in the city are significant in quantity. The amount of solid waste generated can be estimated about 1.5 kg per person per day. The average amount of liquid waste collected and disposed from the city of Harar is about 24m3 per day. The municipality has 3 lifting trucks to collect transfer containers, 1 truck for refuse collection and 24 garbage collection containers of 8m3 capacity placed in different parts of the town. According to the information from Head of Health and Environment Section of the municipality, on average, the municipality manages to collect about 29,500m3 of solid waste in a year. Based on this performance, it has been estimated that about 57% of the daily generated solid waste is collected and dumped. The remaining significant amount of solid waste is disposed of along roads riversides, and near residential areas. In addition, according to house-to-house survey conducted by Harar Health Bureau and the 1994 and Housing Census, about 29% of the house units in the town do not have sanitation facilities. Inhabitants of this large number of the housing units usually defecate along riverbanks, in open spaces, along the roadsides, in other unauthorized areas. The problem is pronounced in Jegol where the settlement is highly congested, having a high density of population. Further the survey reveals the type of toilet facilities and number of households using these facilities. Accordingly, of the total sample households, about 7.9% of have flush toilets, 61.1% have pit latrines, and 28.7% have no toilet and the remaining 2.2% is not stated.

Based on the survey conducted by Harar Health Bureau (Hygiene, Sanitation & Environmental Section) in July 2003 out of the total 15,735 households, about 11,707 have toilets, while 4,027 do not have any type of toilet facilities. According to this survey, 25.6% of the households do not have sanitation facilities The study further reveals that out of the total 11,7097 toilet facilities, about 6,258 (53.50%) are owned privately, while the remaining 5,449 (46.50%) are shared. The following tables show distribution of the toilet facilities and number of households using these facilities.

Table 1. Number of households and distribution of toilet facilities in each kebele of Harar town, 2003

Kebele	Dry Pit Latrine	VIP Latrine	Flush Toilet	Total	Private	Shared	Total
01	595	23	85	703	317	386	703
02	600	10	65	675	315	360	675
03	340	16	6	362	173	189	362
04	173	6	0	179	121	58	179
05	392	1	46	439	190	249	439
06	324	0	20	344	163	181	344
07	480	0	15	495	235	260	495
08	821	39	87	947	389	558	947
09	899	59	18	976	620	356	976
10	777	5	71	853	258	595	853
11	443	0	23	466	259	207	466
12	1,048	35	11	1,094	506	588	1,094
13	359	62	69	490	267	223	490
14	458	6	72	536	263	273	536
15	325	203	10	538	321	217	538
16	453	192	96	741	607	134	741
17	528	43	161	732	416	316	732
18	621	32	58	711	546	165	711
19	423	2	1	426	292	134	426
Total	10,059	734	914	11,707	6,258	5,449	11,707

Source: Harar Health Bureau, Hygiene & Environmental Health Team, Environmental Health and Sanitation Coverage study, July 2003 (Hamle 1996 E.C.).

Based on the survey findings, the number of toilet facilities available in higher 01 that comprises kebeles 01-07 is lower compared with the others, this might be due to lack of space to construct latrines because of crowded residential houses and densely populated old town of Jegol. The problem is further compounded as new development in this area is not allowed, to preserve the historical heritage and not disturb the existing settlement/layout pattern of the area.

As per the Regional Health Bureau survey findings, the sanitation facility of the town has slightly improved compared with the survey carried out by CSA in 1994. Considering that the data is recent, reflecting the current health facilities of the town, the consultant proposes using these data as a basis for projection the types of toilet facilities in the study

Q2. Strategic selection of disposal practice – What is most commonly done with sludge/faecal sludge/septic waste/excrement in your country or region? Does it go to lagoons? Is it put in landfills or incinerated? Is it composted or treated in any way to make it usable on soils? What options are used? Please discuss in order from most common method to least common method.

The municipality does not have an appropriate solid waste disposal site. The solid wastes are dumped in rural areas of the region. As the result, dwellers near these dumpsites have complained on the grounds of various environmental problems, including odours and an unpleasant environment.

In addition to these, about 200 communal dumpsites have been constructed in various parts of the city. Some of them often use the solid wastes as a fertilizer. There are also attempts to promote the use of incinerators in some organizations. With regard to hospital wastes, the existing Hospital in the region disposes of the wastes generated within their compound and, after a time, they bury it.

Q3. How are the decisions made as to what to do with it? Is risk assessment involved? Are decisions driven by cost, practicality, availability of equipment or labor – what drives decisions? Who makes the decisions?

The solid and liquid waste management of the city is carried out by the municipality's Social Services Department, urban sanitation and environmental protection team. So the decision concerning waste management is made by the municipality. However, existing manpower is not adequate to handle/manage the generated solid and liquid wastes in the city, which is about one sanitation worker per 200 dwellers.The institutional problem of the city with regard to solid and liquid waste management may be resolved after the implementation of the new institutional arrangement, under which the unit is supposed to be elevated to a higher status, i.e., the Urban Sanitation and Environmental Protection Department within the Urban Sanitation, Environmental Protection and Beautification Authority.

Q4. What does it cost to dispose or use sludge/faecal sludge/septic waste/excrement?

There is no payment to dispose of the wastage or to use sludge because the municipality disposes outside the city as discussed above.

- Charge to customers for treating one cubic metre of sewage – 150 Birr per truck.
- Cost of 1000 litres of diesel fuel – 6.75 Birr per litter
- Cost of one kilowatt hour of electricity – On average, 0.57 Birr/KWH

Q5. Please describe the processes of treatment, use, and/or disposal for the most common ways of use or disposal identified above.

We don't have a waste treatment plant, and the current practice of dumping solid and liquid waste indiscriminately has health, environmental and social impacts that have to be addressed through proper investigation and design. Therefore, there is an immediate need to have designated and well designed and managed disposal sites for solid and liquid waste. Further, the technical and financial capacity of the municipality is not at such a status as to manage the waste being generated in various portions of the town. A shortage of trucks for transporting solid and liquid waste and the absence of properly prepared dislodging sites are the main problems of the town in solid and liquid waste management.

Q6. If it is used in agriculture, please describe how it is managed. Are there requirements regarding the soils receiving the material? What other requirements are there?

Actually, local farmers use excreta as a fertilizer without any preprocessing of the waste, so as a result, there is contamination

Q7. If it is used on food crops or on lawns, parks, or playing fields, please describe how it is managed. What measures are taken to prevent contamination or disease transmission? Are there requirements regarding the soils receiving the material? What other requirements are there?

It is used for cereal plants by local farmers, but it is not done by the regional government or institutional level. It also depends on the access road to the farmland.

Q8. If it is used for land reclamation or in forestry, please describe how it is managed.

No, we don't use it

Q9. If it is placed in landfills, please describe how it is managed.

No, we don't have landfills, the waste of the city is deposed in an open agricultural area

Q10. Laws and regulations should be summarized as succinctly as possible for each management option discussed above and in the most detail for the preferred option. Does risk assessment underpin these laws and/or regulations? If so, please discuss.

The Harari people National State Conservation Strategy (RCS) was prepared in 2002 in five volumes and it was approved by the Region Council.

The regional conservation strategy reports are comprehensive, detailing the resource basis; institutional policy and legal requirements for a sound environmental management. These documents could be used extensively as a basis to develop different regulations, such as environmental pollution controls, environmental impact assessments, municipal solid waste management, environmental standards etc. Thus, the documents need to be updated regularly, which has not been carried so far, and which needs to be treated as a gap. The federal Hygiene and Environmental sanitation regulation has been endorsed and is in place and the region's Hygiene and Environmental sanitation was also prepared four years ago, but still has not been ratified. Although there is no networking and coordination among institutions, individuals and organizations of the region, some efforts on rapid assessment of the city waste management are being done. The French city, Charleville, crew assessment book, Tropics consultation report, students thesis writings are the case in point. Regarding the operation of the waste management of the city, the following could be cited among the various possible interventions.

- The involvement of the municipality in the operational activity of the solid waste management.
- The coalition of the municipality and the Harar water supply and sewerage authority for liquid waste management.
- The promotion of the "donkey solution" as a local response for the problem of the city solid waste collection activities.
- The introduction of fees for waste management activities of the city. Every household and institutions would be required to pay for the service it is getting.

Q11. If mechanical dewatering is required typically to facilitate a successful operation, please describe briefly why this is so and the techniques employed.

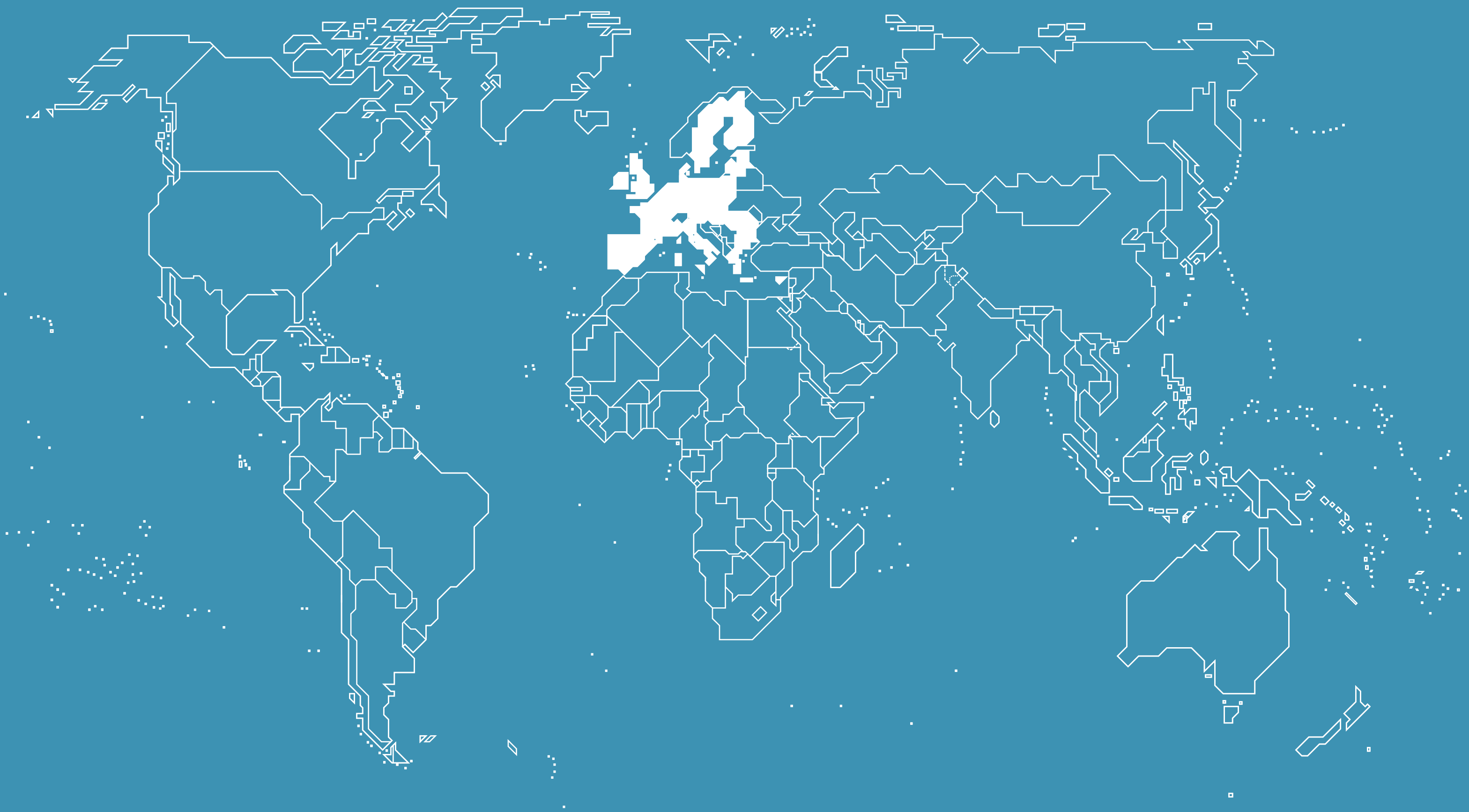
No, we don't require dewatering, because there is no waste treatment plant.

Q12. Equally, please describe any stabilization and or disinfection techniques used to render raw sludge, faecal matter, etc. suitable for use or disposal.

No, we don't have any techniques

Q13. Please identify any 'hot issues' that could ultimately lead to a modification of the rules and regulations. If changes are planned or are imminent please summarise the changes with planned dates.

The absence of clear policy and working guidelines, weak community awareness programs, insufficient follow-up and supervision, and low level capacity and consciousness of the small scale enterprise contribute to the existing weak private-public interactions. There is no NGO and private sector involvement in the waste management activity of the city.



European Union

Author: Peter Matthews

European Union

BACKGROUND

The Union is made up of 27 countries, each at different stages of investment in waste treatment services according to when each country joined the Union. Twelve countries, mostly from Central and Eastern Europe, joined the Union on the 1 January 2007. The existing Members at that time are referred to by the acronym "the EU-15."

Proposals for policies and legislation are made by the European Commission, often after extensive programmes of research and investigation. After expert working groups have discussed and recommended amendments, and with inputs from other organs of the Union, particularly by passage through the Parliament, they are adopted by the Council of Ministers (in the case of waste water treatment by the Environment Ministers). The most usual form of legislation is a Directive, which must then be adopted by each Member State and implemented according to rigorous timetables. Although an original Directive specifies compliance deadlines, if a Member State accedes to the Union after that date, a modified programme is agreed to as part of the accession. As a result, the new Member States are some way behind the established Members on matters relating to waste water treatment. The first edition of the Atlas gave an extensive summary of EU legislation in 1995. Since that time, information has become readily accessible on the internet and further information on current legislation can be found on the website for the European Union

ROUTES FOR DISPOSAL AND USE

Collecting current data is notoriously difficult, but by analysing a variety of available statistics, it can be deduced that for the EU-15 the following routes of disposal are expected in 2010 for approximately 9 MtDS /yr

- Landfill 18 %
- Other 7 %
- Thermal 23 %
- Composting 7%
- Agriculture 45%

With the accession of the new 12 Members, the production is likely to rise by about 25%, with a bias towards use on land, particularly in agriculture. The total figure should be taken as an indication rather than an absolute figure.

So if composting is included in the land use category, there is more than a 50% chance that the benchmark sludge in a European city would be treated and used on land as biosolids. The principal alternative is by thermal destruction, with a growing trend of energy recovery. Landfill is being phased out for practical and regulatory reasons

The selection of management on a local basis will be achieved by a variety of means, but the statistics reported above obscure the fact that local practices vary very widely. So, for example, recycling is encouraged in the UK, but banned in the Netherlands, where sludge is used as a biofuel. Even within countries, practices can vary widely due to local factors – even having local bans on agricultural use or incineration. The Atlas provides some European comparisons.

RELEVANT LEGISLATION

The longest-standing Directive relevant to this Atlas is the Directive on the use of sewage sludge in agriculture, agreed to in 1986. Because biosolids use was already a widespread practice at that time, it was considered appropriate to have it controlled. Of course, many Member States had some form of regulation already. This was agreed to after a very long programme of research in the COST 68 programme, which lasted for over a decade. Other Directives concern the landfill of waste in 1999 and the incineration of waste in 2000. The investment in waste water treatment was given a very big boost by a Directive in 1991. This created substantial increases in sludge production – more in some countries than others. This Directive also encourages the use of sewage sludge in agriculture.

In most, if not all, EU countries, the requirements of the Directive for the use of sewage sludge in agriculture have been exceeded, although the additional requirements vary from country to country

THE 1986 DIRECTIVE FOR THE USE OF SEWAGE SLUDGE IN AGRICULTURE

The Directive recognizes that some chemicals present in sludge accumulate in the soil. These are controlled by setting maximum concentrations in the soil (as mg/kg dry solids) and maximum concentrations in the sludge (as mg/kg dry solids) or maximum rates of addition expressed as an annual average over a 10-year period. Limits are set for total zinc, copper, nickel, cadmium, mercury and lead, and consideration is still being given to chromium. After careful consideration, it was decided that limits were not needed for trace organics. It may well be that individual Member States will impose national limits for such substances.

The soil limits are set for neutral soil at pH6-7; a 50% increase is allowable in more alkaline soils (which also contain more than 5% calcium carbonate). Decreased limits must be defined for more acidic soils with no sludge applied to land with a pH value of less than 5.0. The sludge and soil limits are set as ranges and each Member State must choose the value to work to, taking account of local conditions. See Table 1

These soil values are to be checked using 25cm samples composited from sub samples of no more than 25 per 5 ha. If the soil depth is less than 25cm, samples must be taken to that depth but no less than 10cm. Analysis of soil must be carried out at a frequency to be determined in each Member State for sludges from works serving a domestic population of more than 5000 people. The analysis for metals must be carried out after strong acid digestion and the reference method must be atomic absorption spectro-photometry. Sludges are to be analysed for pH, the dry and organic matter nutrients and metals, but the soil only for pH and metals.

The Directive also waives the soil limits for land dedicated to sludge disposal but used for agricultural crops at the time of implementation of the Directive in June 1986. This is with the proviso that there is no hazard to health or the environment and there is restriction of the crops as animal foodstuff where the defined soil limits are exceeded.

Only the nutrient requirement of crops must be provided and water pollution must be avoided.

The Directive does not define numerical micro-biological criteria because, at the time the Directive was formulated, the view was that the heterogeneous nature of sludge made sampling difficult and analytical measurement was too difficult on a routine basis. Protection was to be afforded by a combination of restrictions on use depending on the origins of the sludge, its treatment and the farming practiced. These were based on prevention of risks assessed by indicator target organisms such as Taenia and Salmonellae. However views in Europe have been changing, and limits for the quality of treated products and the reduction of the content for example of E. Coli during treatment are being considered as indicators of process efficiency

Sludges that have not been treated by biological or chemical means or by long-term storage so as to reduce fermentability and health hazards arising from their use must not be applied to land unless they are ploughed in immediately or injected. Where treated sludge is applied to grassland or forage crops, grazing or harvesting must not be done in less than 3 weeks. No sludge must be applied to growing fruit and vegetable crops, except fruit trees or applied to land used for growing fruit and vegetable crops which are normally in direct contact with soil and are eaten raw, in the period of 10 months preceding the harvest and during the harvest.

The disposal authority must keep a register of information on the quantities of sludge produced and supplied, nature and composition (except for works of below 5,000 pe), and treatment and location of farms receiving the sludge. This information must be available for inspection by competent authorities and used in a consolidated national report to the Commission in 1991 and every 4 years thereafter. Information on the sludge must also be provided to its users. Member states were given 3 years from June 1986 to implement the Directive.

The European Commission has been engaged in a process of review of the Directive for some time.

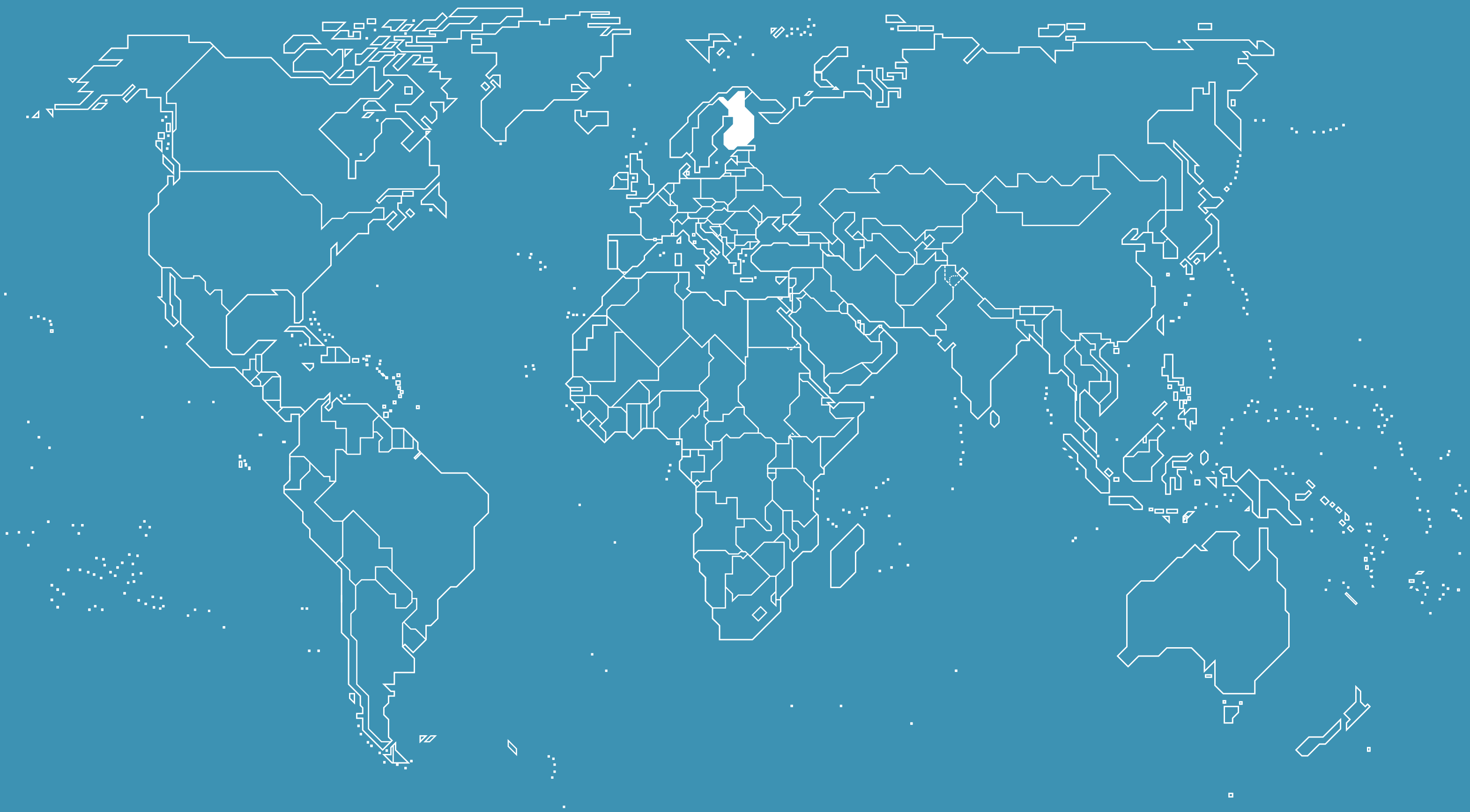
Table 1. EC directive restrictions on metals in sludges and soils during agricultural use

	Soil mg/kgDS (1,2)	Sludge mg/kgDS	Rates of application KgDS/ha/yr(3)
Cadmium	1-3	20-40	0.15
Copper	50-140	1000-17500	12.0
Nickel	30-75	300-400	3.0
Lead	50-300	750 – 1200	15.0
Zinc	150-300	2500-4000	30.0
Lead	1-1.5	16-25	0.1

1. pH 6 - 7, but Cu, Ni, Zn limits can be increased by 50% in soils of pH >7.

2. Where dedicated land used for farming and sludge disposal and exceeded these values in 1986 and it can be demonstrated that there is no hazard, and commercial crops are grown and used only for animal consumption, the practice may continue.

3. 10-year average, can be applied in one go.



Finland

Author: Pirjo Rantanen

Finland

BACKGROUND

This text is prepared as a contribution to the Second Edition of the Global Atlas of Wastewater Sludge and Biosolids Use and Disposal – The Moncton Project. It concerns a whole country, thus it does not follow the given procedure, but gives an overview of sludge disposal in Finland. This text is prepared at the Finnish Environment Institute (Syke).

AMOUNTS OF SLUDGE

The total amount of municipal sewage sludge formed in Finland was ca. 0,15 M t in 2004 and 2005 (Table 1). Only 3-8% of the sludge was used in agriculture. The rest is used in landscaping. (Syke, 2007)

Ca. 4 314 000 of inhabitants lived in cities or smaller towns in 2005 (Santala et al. 2006). This number can be used to estimate the amount of formed sludge per person: 94 g d^{-1} $person^{-1}$.

Table 1. The amounts of municipal sewage sludge formed and used in agriculture and the population of Finland and the amount of formed sludge in grams per person per day in 2004 and 2005

	2004	**2005**
Total amount of municipal sewage sludge(t a^{-1})	149 900	147 700
Sewage sludge used in agriculture(t a^{-1})	11 600	4 200
Inhabitants in cities or towns		4 314 000
Municipal sludge formed (g d^{-1} $person^{-1}$)		94

CONCENTRATIONS OF HEAVY METALS AND NUTRIENTS

The concentrations of heavy metals and nitrogen and phosphorus were well below the levels required in the Sludge Framework Directive and also below the more stringent Finnish requirements in 2004 and 2005 (Table 2). The concentrations of nutrients were 3,4-3,8 % of nitrogen and 2,2-2,4 % of phosphorus in the total solids of the sludge.

Table 2. Concentrations of heavy metals and nutrients in Finnish sludges (Syke, 2008)		
Element (heavy metal or nutrient)	**Concentration (mg kg^{-1}TS^{-1}) 2004**	**Concentration (mg kg^{-1}TS^{-1}) 2005**
Cd	0,60	0,60
Cu	251	244,
Ni	22,2	30,3
Pb	12,0	8,8
Zn	358,	332
Hg	0,62	0,37
Cr	30,9	18,1
N	38 000	34 000
P	22 000	24 000

LEGISLATION

Finland has new legislation concerning the use of biosolids as fertilizing products. Government Decree (539/2006) concerns all uses of biosolids-derived products except use at landfills. The Decree includes regulations concerning potentially harmful elements, pathogens and pathogen indicators in fertilizing products. The regulations relate both concentration limits in products as well as allowed spread amounts. The spread amounts of nutrients are also regulated. The Decree also stipulates which methods are valid as producing biosolids products of good hygienic quality. Old legislation, which is the national implementation of Sludge Framework Directive, is still enforced. An overview of the concentration limits is in Table 3. More can be found in *http://www.finlex.fi/fi/viranomaiset/normi/400001/28518* in Finnish and Swedish.

Table 3. Concentration limits for fertilizing products in mg kg^{-1} TS^{-1} if dimension is not mentioned

	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Salmonella	Escherichia coli
Concentration limit	1,5	300	600	1	100	100	1500	25	Not detected in a sample of 25 g (0/25 g)	<1000 cfu

The listed methods for sludge treatment are thermophilic anaerobic digestion, thermal drying, composting, lime stabilization, chemical treatment. Other methods can also be validated, i.e., each new method has to prove to produce a product with a consistently good hygienic quality.

TYPICAL TREATMENT PROCESSES

The most typical sludge treatment process in Finland is composting, which is done in windrows, reactors or both. Mesophilic anaerobic digestion is also common in the largest cities.

Other methods include lime stabilization, thermal drying, incineration thermophilic digestion and chemical treatment with H_2SO_4 and H_2O_2. According to a survey 73 % of the Water and Wastewater Works compost their sludges (Sänkiaho and Toivikko, 2005). The other methods are marginal, though there is pressure to find new methods to ensure the quality of the final product in the market, especially hygienically.

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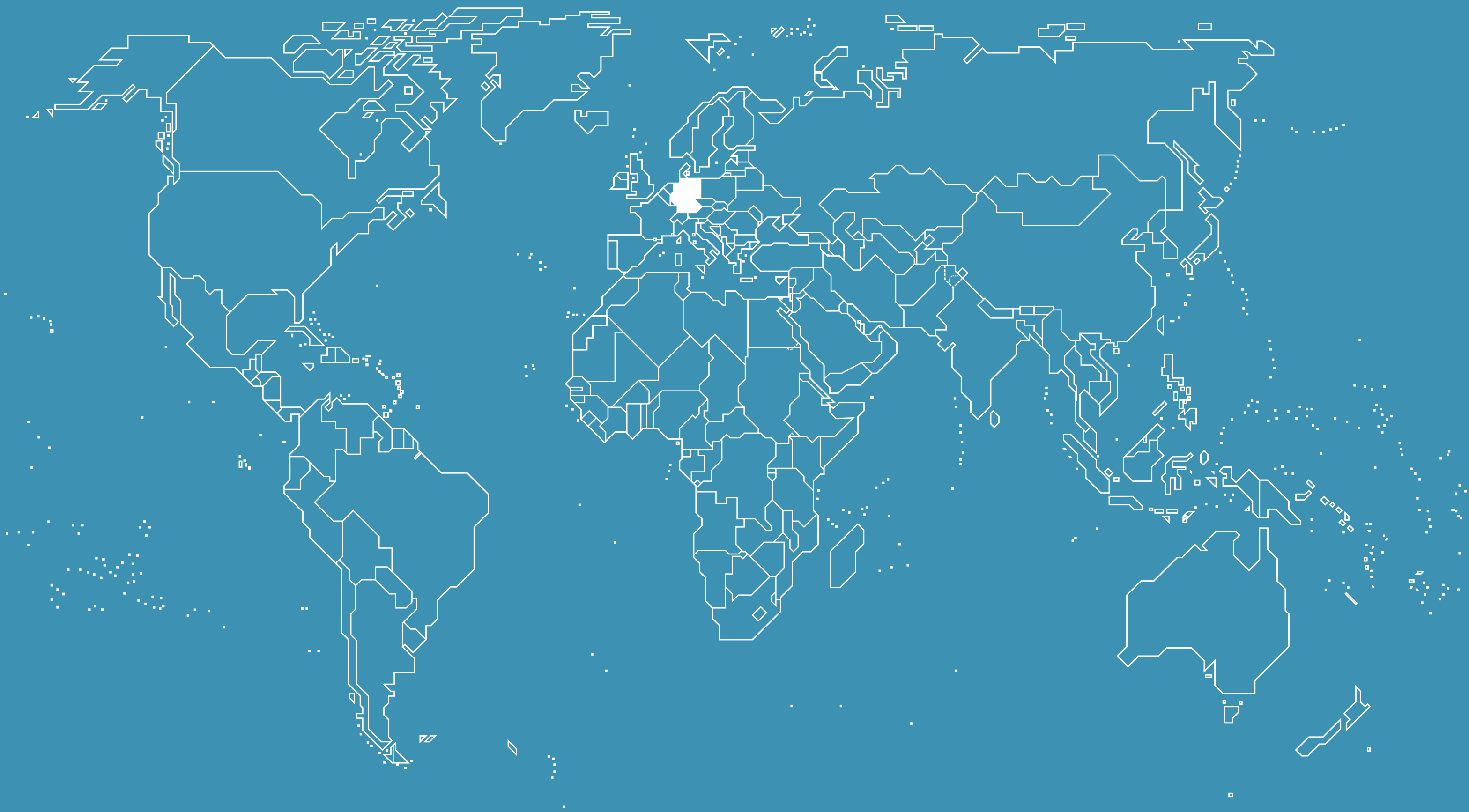


Germany

Author: Nadine Schulte

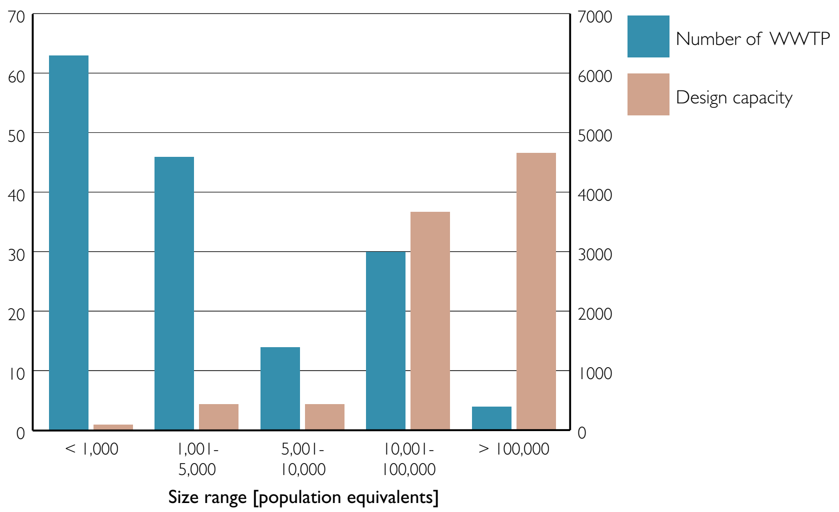
Germany

SITUATION OF SEWAGE SLUDGE DISPOSAL IN GERMANY

Reinhard Reifenstuhl, Hennef

Today, about 10.000 municipal wastewater treatment plants are in operation in Germany. Regarding the number of plants, it has to be considered that only approximately 250 of the biggest plants (with design capacities of more than 100.000 population equivalents [pe]) treat about 50% of the wastewater volume, while a further 7.000 small sewage works (with design capacities less than 5.000 pe) contribute to less than 10 % of treatment capacity. The relationship between number and capacity of German wastewater treatment plants is shown in figure 1.

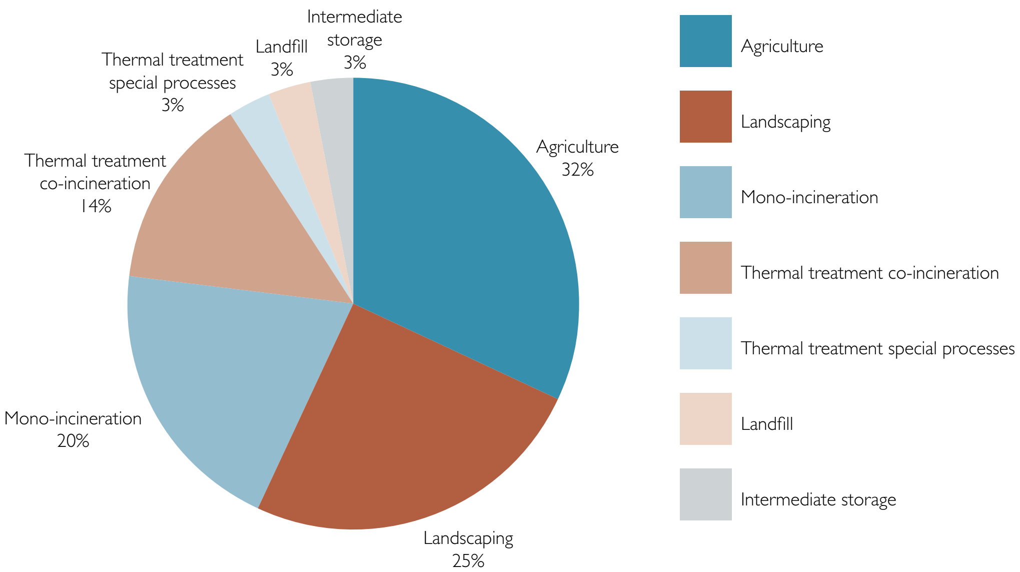
Figure 1. Number and design capacities of waste water treatment plants (wwtp) in Germany in 2003 [1]



About 94 percent of the wastewater volume is treated according to a high standard that comprises biological treatment with nutrient elimination, including a tertiary purification step [2]. For specific local requirements, it is possible to add further elements. The average degradation degrees are 81 percent for nitrogen, and 90 percent for phosphorus[3].

In 2003 approx. 2 million tonnes of sewage sludge (dry matter) a year are produced in Germany. A substantial increase of sewage accumulation in future is not expected due to the existing high connection degree to the public distribution network and thus to the sewage treatment plants. Figure 2 shows the distribution of different ways of disposal for sewage sludge in Germany.

Figure 2. Methods of sewage sludge disposal in Germany in 2003 [1]



Over the past few years, thermal procedures have gained greater importance, at the expense of landfilling as well as material recycling (agriculture, landscaping). In particular this is due to the following two developments:

1. Since 2005 landfilling of sludge is no longer possible in Germany, as it is no longer legal to dispose of materials with a total organic content (TOC) of more then 3% in this way.
2. The political discussion about sludge recycling in agriculture or landscaping, which went on during the past few years in Germany caused a lot of uncertainty. This discussion included not only the introduction of considerably higher requirements, but a complete ban on sludge recycling too. In consequence, some operators of sewage treatment plants felt sludge recycling to agriculture might not be a reliable disposal method in Germany anymore and therefore prefer thermal treatment as the safest choice.

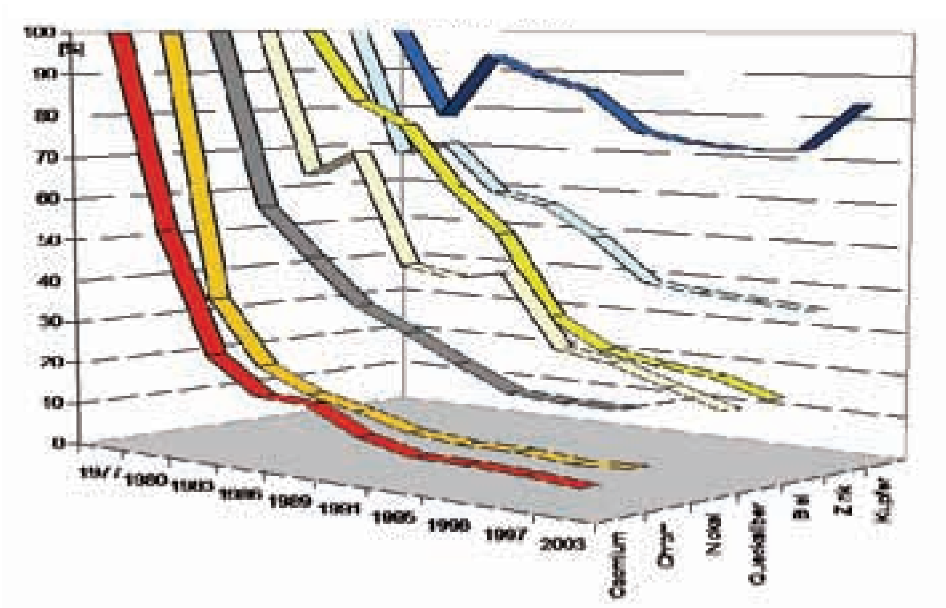
SEWAGE SLUDGE QUALITY

The DWA survey of 2003 [1] shows that the contents of pollutants in municipal sewage sludge in Germany is far below the limits of the applicable German Sewage Sludge Ordinance and that the positive development of the sewage sludge quality in general continues (see table 1). A comparison with the nationwide data on the quality of agriculturally recycled sewage sludge, published by the Federal Environmental Agency (FEA) in 1997, shows that the quality of sludge for the ecotoxicologically most relevant heavy metals, i.e. cadmium, lead and mercury, has further improved, with the reductions amounting to 14 to 18 percent. This, however, is in contrast to increasing contents of the elements copper and nickel in a similar extent (15% Cu, 20% Ni). These could, amongst other factors, be ascribed to the increased use of these substances for installations of drinking water and wastewater systems (mains, fittings, gutters). Figure 3 illustrates the significant decline of heavy metal contents in sewage sludge during the period 1977 to 2003.

Table 1. Average heavy metal contents of sewage sludge in Germany (1991 to 2003) [mg/kg ds] [1]

	All sludges	Sludges recycled in agriculture & landscaping					
					Trend		Germ. Sludge Ordinance
Parameter	**DWA 2003**	**FEA 1991**	**FEA 1997**	**DWA 2003**	**91 to 03**	**97 to 03**	
Lead (Pb)	61,7	93	63	51,9	- 44	- 18	900
Cadmium (Cd)	1,52	2,1	1,4	1,20	- 43	- 14	10
Chrome (Cr)	60,5	59	46	50,1	- 15	+ 9	900
Copper (Cu)	380,2	286	274	316,1	+ 11	+ 15	800
Nickel (Ni)	32,2	31	23	27,6	- 11	+ 20	200
Mercury (Hg)	0,92	2,1	1,0	0,82	- 61	- 18	8
Zinc (Zn)	955,7	1076	809	788,6	- 27	- 3	2500

Figure 3. Development of heavy metal contents in sewage sludge in Germany (1977 to 2003; heavy metal content in 1977 = 100%)



Another positive trend is the development of the amount of organic pollutants in sewage sludge (see table 2). In contrast to the data of the FEA of 1996, significantly reduced contents of pollutants have been registered for all parameters provided pursuant to the Sewage Sludge Ordinance. The reductions of dioxins and furans amount to 44 percent, those of adsorbable organically bound halogens (AOX) amount to 12 percent, and polychlorinated biphenyls (PCB) amount to 55 percent. As expected, the collected data also shows that the sewage sludge recycled in agriculture and landscaping have significantly lower contents of pollutants than the sludge subjected to thermal treatment.

Table 2. Average contents of organic substances in sewage sludge in Germany [mg/kg ds] [1]							
	all sludges	**sludges recycled in agriculture & landscaping**					
	DWA	**FEA**	**FEA**	**DWA**	**Tendenz**		**AbfKlärV**
Parameter	**2003**	**1994**	**1996**	**2003**	**94 zu 03**	**96 zu 03**	**(1992)**
AOX	185,7	206	196	172,8	-16	-12	500
PCB	0,08	0,158	0,156	0,07	- 56	- 55	1,2
PCDD/PCDF [ng TE/kg m_T]	10,1	22	17	9,56	- 57	- 44	100
PAK[1]	3,26	k.A.	k. A.	2,16	-	-	-

1. Total of the following substances: Acenapthen, Phenanthren, Fluoren, Fluoranthen, Pyren, Benzo(b+j+k)fluoranthen, Benzo(a) pyren, Benzo(ghi)perylen, Indeno(1, 2, 3-c, d)pyren

About a third of the sewage sludge produced in Germany is used as a fertilizer in agriculture to reuse the high nutrient content of the sludge, particularly phosphorous. Table 3 shows average nutrient contents of sewage sludges in Germany.

Table 3. Average nutrient contents in German sewage-sludge [g/kg ds] [1]	
Parameter	**DWA 2003, Average nutrient content**
Nitrogen	35,4
Phosphorus (P_2O_5)	55,4
Potassium (K_2O)	4,03
Magnesium (MgO)	9,7
Calcium (CaO)	102,9

LEGAL REQUIREMENTS FOR AGRICULTURAL UTILIZATION

There are quite a number of restrictions governing agricultural utilization. These concern documentation, analysis, application and the notification of authorities. Maximum permissible values for heavy metals and organic pollutants must be observed and are given in table 4.

Even though the use of sewage sludge is strictly regulated, many experts consider the maximum permissible values as too high, as the laws governing the use of sewage sludge in agriculture were passed in 1992. New legislation regarding the use of sewage sludge in agriculture is in preparation and in November 2007 the Federal Environment Ministry published a draft for a new sludge ordinance. One of the main issues of this draft is a significant reduction of existing limit values for heavy metals. In addition new limit values for further organic substances are proposed. Table 4 shows the maximum permissible values which are in force today as well as those that have been proposed by the Federal Environment Ministry. For comparison, data about the average quality of sludge in Germany is provided within the last two columns.

Table 4. German and European requirements for the application of sewage sludge to agriculturally used soils and average qualities of sewage sludge in Germany [mg/kg ds]

Parameter	German Sludge – Ordinance (1992)	Proposed limit values (November 2007)	European Guideline (1986)	Average quality of German sewage-sludges (2003)	
				all sludges	sludges recycled in agriculture & landscaping
Heavy Metals					
Pb	900	120	1.200	62	(52)
Cd	10	2,5	40	1,5	(1,2)
Cr	900	100	-	60	(50)
Ni	200	60	400	32	(27)
Hg	8	1,6	25	0,9	(0,8)
Cu	800	700	1750	380	(316)
Zn	2.500	1.500	4.000	956	(789)
Organic Pollutants					
AOX	500	400	-	186	(173)
PCB	0,2 (each congener)	0,1 (per congener)	-	0,08	(0,07) *
PCDD/F	100 ng	30 ng	-	10	(9,6)
B(a)P	-	1	-		

* *total of 6 congeners*

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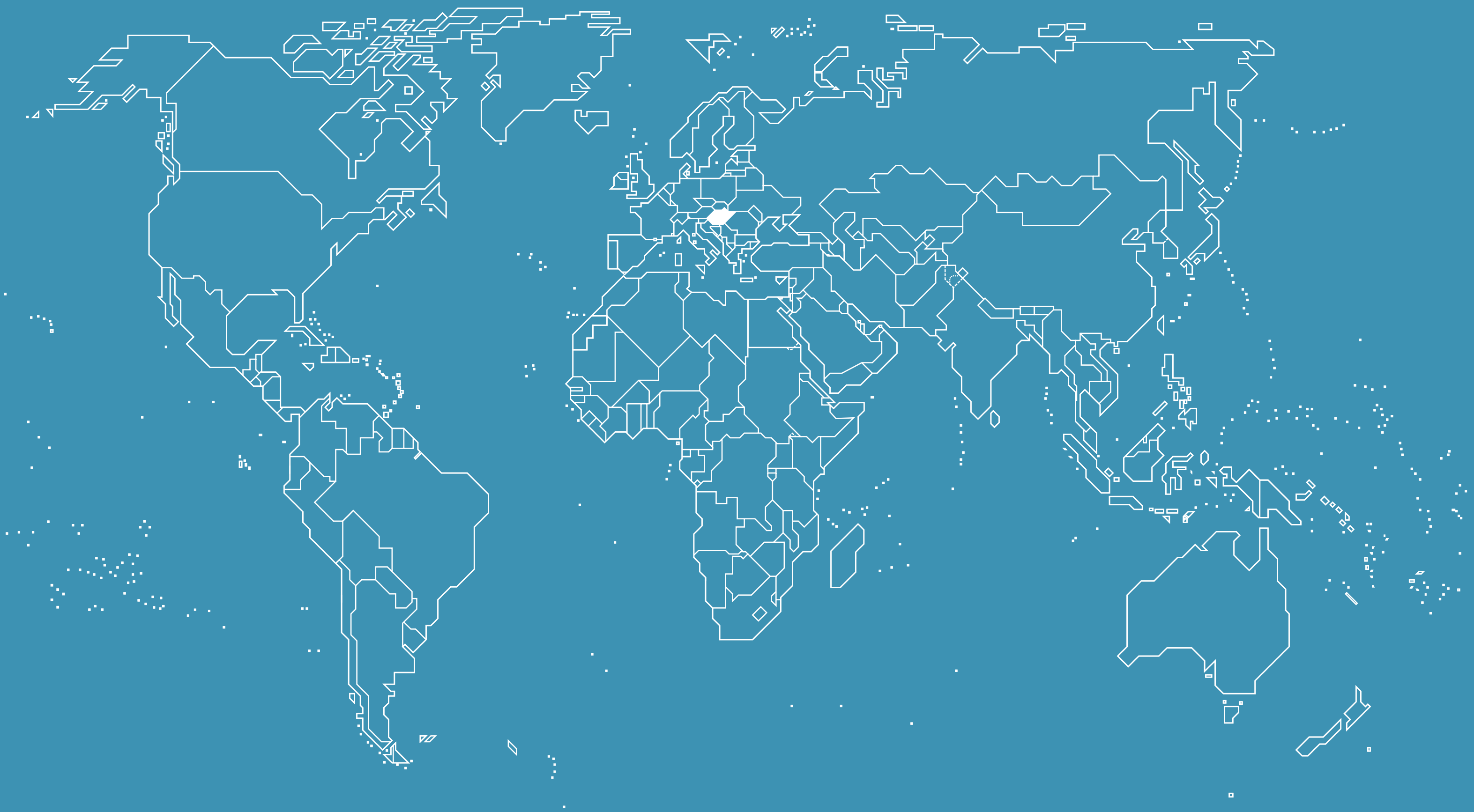


Hungary

Author: Gyorgy Garai

Sludge disposal in Hungary

MAIN DATA

- Population of Hungary: 10 000 000
- Inhabitants connected to sewer: 68%
- Sewage collected: 560 000 000m^3

Sewage collection, treatment and sludge disposal is the task and responsibility of the municipalities.

TREATMENT OF THE SLUDGE

In Hungary, the typical wastewater treatment technology is the activated sludge process. Small plants do not have primary sedimentation generally, the generated sludge is waste activated sludge. Large plants have primary sedimentation, the output sludge is mixed sludge (raw+waste activated). The total sludge dry matter is about 120 000 ton/year. Sludge dewatering is performed by belt filter press or centrifuge. The typical dry content is around 18-20%.

At the biggest treatment plant (Budapest, North-Budapest Wastewater Treatment Plant) membrane presses are operated. Dry content: 36-38%.

At large plants, digesting and biogas production is usual. Mesophilic digestion is usual. Thermophilic digestion is very rare. At some plants, electric energy is produced by gas engines.

DISPOSAL OPTIONS

Table 1. Annual quantities of sewage sludge (tds/year)

Total	Incineration	Agriculture	Landfill	Forestry	Other
120 000	1000	47 000	72 000	0	0

The goal of the government is to decrease landfilling and increase the ratio of agricultural use. For 2015 the ratio of landfilling will be 33%.

ECONOMIC INFORMATION

- Price of electric energy: around 25 HUF/kWh (varies widely, depending on the voltage, contracted performance, magnitude of consumption and other factors)
- Average sewage charge (weighted by consumption) 245 HUF
- Diesel fuel price: 300HUF/litre

AGRICULTURAL UTILIZATION

Regulation of agricultural use doesn't include recultivation (land reclamation), but sludge used for recultivation is included in the yearly sum. There is no regulation for sludge use in recultivation.

Sludge is used in thickened condition (injection), or in dewatered condition. A small proportion is dried.

In the case of agricultural utilization, the limit values for sludge concentration come from two different Hungarian regulations. The first is connected to compost product (not mentioning the origin of the compost, so it can refer to compost produced [partially] from sludge}. The second one is aimed directly at sewage and sludge agriculture – 8/2001. (I. 26.) decree of Ministry of Agriculture about the authorization, storage, trade and utilization of yield-increasing materials.

Table 2. Limit values for sludge concentration

	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Se
	Maximal content mg/kg dry content								
Composts	10	2	50	100	100	1	50	100	5

Table 3. Limit values for sludge concentration – Organic pollutants

Total PAH (16 kind of chemicals)	**<1,0 mg/kg dry cont.**
– benz(a)pirene	<0.1 mg/kg d.c.
– (TPH C5-C40)	<100.0 mg/kg d.c..
– total PCB (7 PCB-28, 52, 101, 118, 138, 153, 180)	< 0.1 mg/kg d.c..
– total PCDD/F	<5.0 ng/kg d.c.. T.E.Q
– Faecal coliform	<10 i/g or 10 db/ml
– Faecal streptococcus	<10 i/g or 10 db/ml
– Salmonella sp.	2x10 g or ml negative
– Human parasite helminth egg	100 g or 100 ml negative

In this case above, the compost is a product, which can be sold, bought and used free, without any special monitoring or authorization.

LIMITS FOR SEWAGE SLUDGE USE IN AGRICULTURE

Regulation of sludge use in agriculture:

- 50/2001. (IV. 3.) decree of the Hungarian Government about the rules of agricultural utilization and treatment of sewage and sewage sludge

Table 4. Sludge limits

Parameter	Limit mg/kg dry cont.
As	75
Cd	10
Co	50
∑Cr	1000
Cr^{VI}	1
Cu	1000
Hg	10
Mo	20
Ni	200
Pb	750
Se	100
Zn	2500

Table 5. Metals in soils (mg/kg)

Parameter	Limit value mg/kg ds.
As	15
Cd	1
Co	30
∑Cr	75
Cr^{VI}	1.0
Cu	75
Hg	0.5
Mo	7
Ni	40
Pb	100
Se	1
Zn	200

Table 6. Maximum annual addition rates (kg/ha)

Parameter	Limit kg/ha/year
As	0.5
Cd	0.15
Co	0.5
∑Cr	10
Cu	10
Hg	0.1
Mo	0.2
Ni	2.0
Pb	10
Se	1.0
Zn	30

On areas qualified as sensitive for nitrate pollution, the maximum allowed yearly dosage of nitrogen is 170kg/ha. This value shall include nitrogen content of sludge and other organic fertilizer (manure)

Pathogens

- Decrease of Fecal coli and Fecal streptococcus by 90%

Cropping cycles

- Not allowed in the case of vegetables and fruits in contact with the soil in the growing year and in the previous year
- Not allowed on meadows and grazing lands
- For grapes, berries, allowed only out of the vegetation period
- In the case of fruit trees, at least 6 months between dosage and harvesting.
- For arable land plants and growing of forage, sludge may be applied in the period between harvesting and sowing.
- pH-of the soil may not be lower than 5.5
- If the pH is in the range of 5.5-6.2, lime shall be dosed together with the sludge
- Soil may not be rough sand of very fine clay (extreme soils are not allowed)
- The active layer of the soil shall be at least 60cm
- Soil may not be frozen or covered with snow or saturated with water
- The pitch of the area may not be more than 12%
- Not allowed on flood areas, areas endangered by inland waters, karstic areas, water resources, meadows, pasturelands

Organics

Table 7. Sludge – Organic limit

Parameter	limit mg/kg dry cont.
∑PAH	10
∑PCB	1
TPH	4000

Table 8. Soil – Organic limit

Parameter	Limit value mg/kg ds.
∑PAH	1
∑PCB	0.1
TPH	100

Table 9. Yearly dosage – Organic limit

Parameter	limit kg/ha/year
∑PAH	0.1
∑PCB	0.05
TPH	40

OTHER RESPONSIBILITIES

Authorization required for the given piece of land from the competent soil and plant protection agency. This authorization shall be based on soil analysis, and on the approval of the competent environmental inspectorate, health authority, and local notary. The authorization is valid for 5 years, after that it can be extended by the same authorization process.

- Soil authority shall be informed 2 days before spreading of sludge.
- Wastewater treatment plant shall record the treatment process parameters, sludge quality and quantity data, sludge disposal data (location of lands, sludge quantities)
- Yearly summary shall be sent to soil authority each year before March 31.
- Soil authority reports summary of collected data to Ministry of Agriculture before each year May 31

LANDFILLING

Regulated by 20/2006. (IV. 5.) KvVM, decree of Ministry of Water and Environment about the landfilling of wastes, and rules connected to landfilling. Sewage sludge allowed to communal waste landfill if it is treated, not contagious, and the dry content is at least 25% and complies the following parameters:

Table 10. Landfill limits

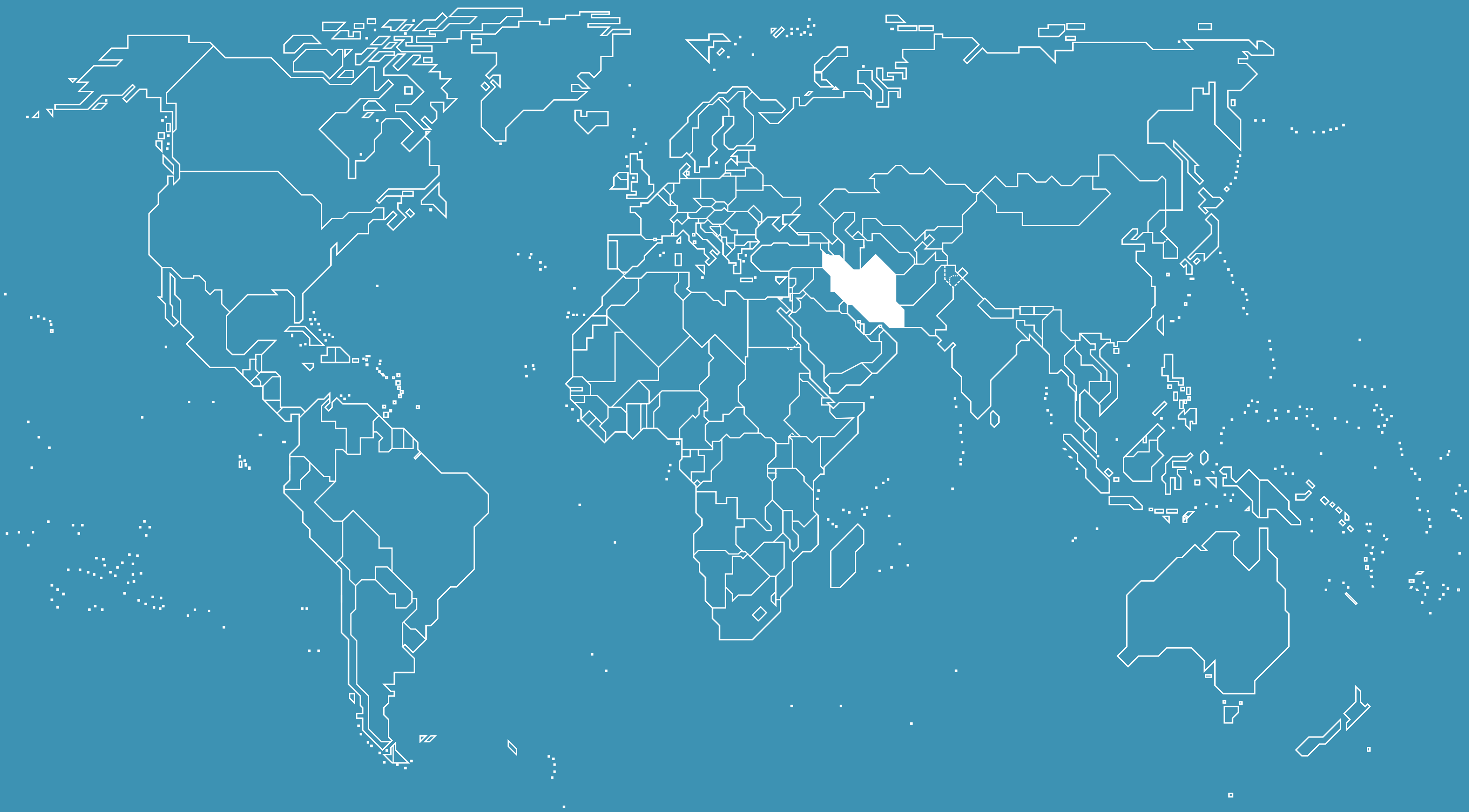
Parameter	Leaching test (L/S = 10 l/kg, destilled water) mg/kg ds
As	2
Ba	100
Cd	1
Cr total	10
Cu	50
Hg	0,2
Mo	10
Ni	10
Pb	10
Sb	0,7
Se	0,5
Zn	50
Cloride-ions	15 000
Fluoride-ions	150
Sulphate-ions	20 000
TDS: total leached solid	60 000

INCINERATION

There are no incinerators for sewage sludge in Hungary. The capacity of hazardous waste incinerators is not high enough to receive significant amount of sewage sludge, and the price of processing is too high (about 100 000HUF/ton). Some cement factories are authorised for sludge incineration. The cost is estimated about (6000 to 10 000HUF/ton). Experimental incineration in cement factory was performed, but it was not applied on a regular basis.

OTHER SEWERAGE WASTES

Screenings are allowed to landfill if not infectious. There is no regulation in Hungary about grit from grit chambers, and sewer sludge coming from cleaning of sewers. These kinds of wastes are generally transported to landfills.



Iran

Authors: Mahmood Ghaheri, Sanam Ghaheri

Iran

The following are the answers to the questions of the "Global Atlas of Wastewater Sludge…" for the "Moncton Project". Before providing the answers, I should clarify that industrial sludges are not included in this report, as there is very poor information in this regard. There are many problems in our country in dealing with industrial wastes including hazardous wastes. Major problems are lack of information about the true amount of these wastes, lack of treatment and disposal technologies, illegal dumping of hazardous wastes, economic aspects and so on. What I can say is that the annual level of industrial wastewaters is about 1.5 billion cubic meters in Iran, and less than 30 percent of these wastewaters have efficient WWTPs. The industrial sludges are categorized in 2 groups — those from organic content wastewaters (textile, tanneries, petrochemicals, refineries, food processing industries etc.) and those from inorganic content wastewaters (metal plating units…). In another categorization, the industrial wastes are categorized in general and specified wastes (usually named as non-toxic and toxic and/or hazardous wastes). The site selection for hazardous waste disposal and well-designed monitoring programs are two important aspects of hazardous waste management in Iran. Hazardous waste disposal sites have been identified and land-filling sites have been selected for hazardous wastes by Department of Environment (DoE).

As except a few cases, there is no kind of mixed wastewater treatment plant in Iran to combine industrial wastewaters with domestic ones, the bio-solid sludge of our WWTPs usually has the following characteristics after treatment:

Dry solid	4.5% w/w
Water content	95.5% w/w
Organic matters	70% w/w
Total Nitrogen	4% w/w
Total Phosphorous	1.2% w/w
Total heavy metals {mostly: Fe and Zinc)	< 100 mg/kg

Now the answers as numbered based on "an optional shorter version of the information requested…":

1. Less than 40% of the total population of our country; Iran, have complete and efficient wastewater treatment plants (WWTPs). The population served by the management of these plants is about 30 million. Less than 40% of the total domestic sludges are being treated completely. This means that: of more than 200.000 cubic meters of daily sludges (2000 tons/day dry solids) of total fecal, septic and waste excrements sludges, only about 80.000 cubic meters (800 tons) is being digested and/or stabilized daily by different methods.
2. The most common method of treatment for these sludges is digestion (aerobically and anaerobically). Lagooning, composting and land-filling are the next methods of treatment. Incineration and mechanical dewatering are usually implemented as final treatment to reduce the volume of the stabilized sludges, although highly toxic and corrosive waste disposal requires incineration. But in a few WWTPs these methods would be applied on the raw or untreated sludges. The stabilized sludge has been used in many agricultural activities from the past to the present.

3. Usually the regional wastewater companies who are responsible for the operation of these WWTPs deliver these treated wastes to the local farmers. The risk assessment is undertaken by a research department in the Ministry of Agriculture. Decision making mostly is based on all of the factors, from cost to practicality and availability of the equipment and/or labor.
4. Referring to 4 questions asked in this part the answers are:
   4.1 The disposal and use cost of sludges, depending on the method of treatment applied, is from 50 cents to $1.50 per cubic meter.
   4.2 Charge to customers for treating one cubic meter of sewage is about 5 cents.
   4.3 Cost of 1000 liters of diesel fuel is $15.
   4.4 Cost of one kilowatt hour of electricity is 3 cents.
5. As mentioned above, digestion is the most common way of treatment for domestic sludges. The digested sludges are usually used for agricultural activities.
6. There is no special management for this usage but the most important factor being considered is attention to the possibility of infection.
7. There are inspection departments both in Department of Environment (DoE) of Iran as well as in the Ministry of Agriculture and in the municipalities. They are responsible and usually supervise these activities.

8 & 9. The land reclamation and foresting uses are in very limited ranges and are ignorable.

10. Unfortunately there are no national regulations and legislation in this regard, but a research department in the Ministry of Energy is assigned to prepare the regulations for this.
11. In a very limited capacity, dewatering systems (mostly filter presses) are applied.
12. The common stabilization technique is the biological digestion but physical and/or chemical treatment systems are applied as well. The conventional chemical treatment is lime application in this regard. The most common disinfection method is thermal, although lagooning and some chemical methods are applied.
13. The environmental issues are very recent and new subjects in our country, especially when speaking about solid wastes, but in recent decades many interested researchers are working hard on solid waste management in the academic sector and industries, as well as in the governmental organizations. Hopefully, it will be seen that the results of these research activities come to application as fast as they should be.

CONCLUSION

Balancing the rate of growth and the needs of an increasing population is a very difficult task for the decision makers in developing countries. Speaking about solid waste management as an example, the responsibility for proper and safe disposal of toxic and hazardous wastes does not fall on the governmental organization (DoE) alone, but requires the cooperation of the industries and the general public.

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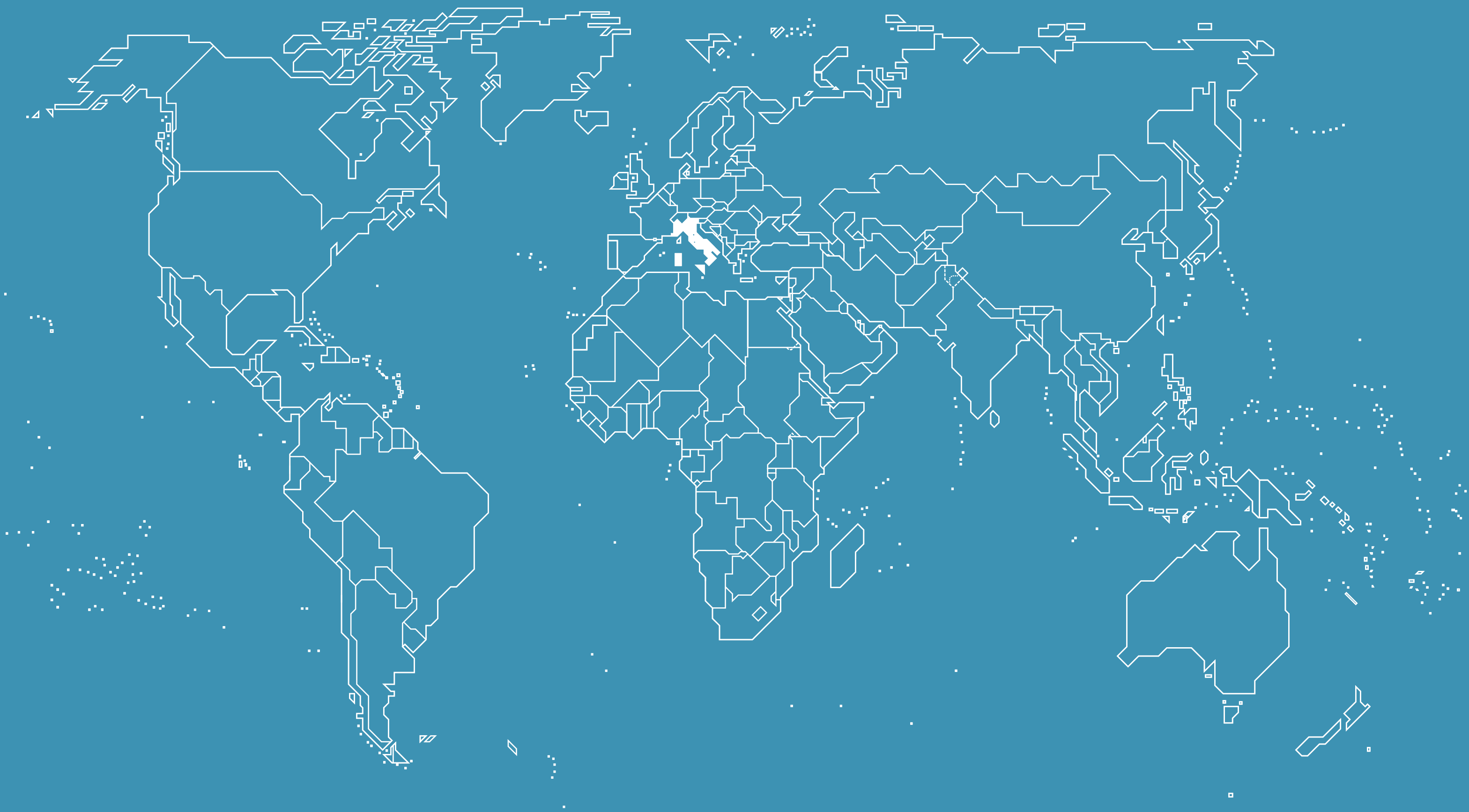

Italy

Author: Dr. Ludovico Spinosa, Roberto Canzian

Italy

INTRODUCTION

In the annual Report by the National Observatory on Wastes on waste management in Italy (ONR, 2006), a production of 4.7 Mt of waste deriving from wastewater treatment plants (CER code 19.08) is reported for 2004. Considering that wastewater treatment sludge (WTS) represents about 90% of above figure, it follows that sludge yearly production is about 4.3 Mt, corresponding to about 1 Mt of dry solids (ds) at a solids concentration of 25%, with an increase of about 10% with respect to years 2001-2003.

According to the Italian National Institute of Statistics (ISTAT, 2006), the total population equivalent (urban + industrial) in Italy is estimated to be around 175 million PE, of which the urban fraction is as much as 102 million PE (55.9% resident population, 14.9% tourists, 16.6% commercial sites, 12.6% crafts and small enterprises). As the average yearly per capita production of dry solids (after aerobic or anaerobic digestion) can be estimated around 30 g-ds/y/PE, the potential Italian sludge production can be estimated around 5,250 t-ds/y, of which about 3,000 t-ds/y is linked to the urban population only. This is a three-fold potential increase if all the population is served by sewerage and subsequent appropriate treatment.

A survey was carried out by Federutility (Association of Water and Energy Local Public Companies), in cooperation with Federambiente (Italian Federation of Public Environmental Services), based on data collected in 2005 and referred to 36 organizations for management of integrated water services serving a total of about 19 million PE (78%, 7%, and 15% in Northern, Central, and Southern Italy, respectively). The wet sludge production accounted for 1 Mt, at 27% dry solids, corresponding to about 22% of the total national production of WTS, and derived from the treatment of about 1.8 million m^3 of wastewater (Pelosi, 2006).

However, it should be noted that sludge management in Italy varies widely as far as local disposal or reuse options are concerned. This is due to different geographical, geological, technical, economic and social contexts; therefore, local situations should be carefully considered as general indications applicable on wider scale.

NORMATIVE DEVELOPMENTS

As Italy is member of the European Union (EU), national legislation on sludge is primarily developed as an enforcement of EU Directives, and generally included in that relevant to wastes and wastewaters.

In particular, environmental matters are mainly regulated by Legislative Decree (DL) 152 of April 3, 2006, recently completed and integrated by the DL 4 of January 16, 2008. DL 152/2006 consists of six Sections, the fourth one specifically dealing with waste management and restoration of contaminated sites, and classifying waterworks and wastewater sludge as "special waste".

Other important regulations regarding wastes, including sludge, are those relevant to incineration processes, and DL 36 of January 13, 2003, as enforcement of European Directive 1999/31/CE on waste landfilling, followed by the Ministry of Environment Decrees (DM) of March 13, 2003, and August 3, 2005, defining criteria for waste admittance in landfill.

The only legislation in Italy specifically addressed to sludge is DL 99 on sludge utilisation in agriculture, issued in 1992 in application of the European Directive 86/278/EEC. The above DL 99/1992 introduces basic conditions and limits for sludge application and utilisation on land, and leaves each Region (Italy is administratively divided into 20 Regions) the possibility to promulgate Regional Directives aimed at adapting general requirements to local situations, including introduction of more stringent limits (Spinosa and Ragazzi, 1996).

However, in recent years, greater attention has been paid in Europe to the recycling of all biodegradable wastes within the context of a sustainable soil policy; this fact, coupled with even more stringent limitations for landfilling of organic wastes, has involved the need for improving the legislation applicable to sludge and other biodegradable wastes. So, (i) the revision of the mentioned EEC Directive for sludge utilisation in agriculture and (ii) the development of a Biowaste Directive have been undertaken by EU. At the moment this process is in stand-by because its completion has been subjected to the development of basis legislation on soil protection, which will then become the reference regulation for the proposed new legislation on sludge and other biodegradable waste.

Due to this delay, and having considered the need of an adjournment of the quite outdated DL 99/1992, some Italian Regions have undertaken the revision of the regional legislation on sludge utilisation in agriculture.

As an example, the Region Emilia-Romagna, in Northern Italy, published a new Regional Directive with Deliberation 2773 of December 30, 2004, modified and completed by Deliberation 285 of February 14, 2005. According to them, the following conditions and limits apply:

- sludge to be utilised must be stabilised through application of one or more aerobic or anaerobic treatments, or equivalent systems resulting in 35-45% reduction of volatile suspended solids concentration, or in a sludge age higher than 30 days (e.g. thermophilic aerobic stabilisation at 55°C with an average retention time of 20 days, thermophilic anaerobic digestion at 53°C with an average retention time of 20 days, mesophilic anaerobic digestion at 35°C with an average retention time of 15 days, conditioning with lime to reach a pH of 12 and maintain it for 24 hours);
- sludge must derive from treatment of wastewaters of certain industrial activities, mainly agro-industrial ones;
- soils for sludge application must have pH≥5, cationic exchange capacity >8 meq/100 g, and heavy metals below certain limits (Cd≤1.5 mg/kg-ds, Hg≤1.0, Ni≤75, Pb≤100, Cu≤100,

Zn≤300); in addition, the soil capacity to oxidize Cr^{III} to Cr^{VI} (test of Bartlett and James) must be <1 μM-Cr^{VI};

- sludge to be utilised must comply with limits for heavy metals (Cd≤20 mg/kg-ds, Cr_{tot}≤1000, Hg≤10, Ni≤300, Pb≤750, Cu≤1000, Zn≤2500, As≤210), agronomic parameters (C_{org}≥20%-ds, N_{tot}≥1.5%-ds, P_{tot}≥0.4%-ds), microbiological characteristics (Salmonella ≤1000 MPN/g-ds), and organic micropollutants (AOX≤500 mg/kg-ds, LAS≤2600, DEHP≤100, NPE≤50, PAH≤6, PCB≤0.8, PCDD/PCDF≤100 ng-TE/kg-ds).

However, analytical controls on sludge utilised in agriculture in Region Emilia-Romagna evidenced an almost constant presence of Toluene and Hydrocarbons, so a research programme to define the limits to be practically fixed for above components has been established by that Region in April 2007. Preliminary theoretical evaluations indicated possible safety limits of 500 mg/kg-ds for toluene and 10,000 mg/kg-ds for hydrocarbons.

PRODUCTION AND DISPOSAL/REUSE

From the mentioned Federutility survey, the specific yearly sludge production per-capita (kg/y/PE) resulted was quite variable due to different plant size, treatment systems, operating conditions, and other local situations: average productions of sludge of 52 kg/y/PE, and of dry solids of 38 g/d/PE were calculated.

A deeper analysis of results showed that the specific sludge production deriving from extended aeration biological plants, or with anaerobic digestion of sludge, and conditioned by polyelectrolytes ranges from 26 to 35 g-ds/d/PE. For treatment plants with chemical-physical treatments and conditioning by inorganic chemicals, production increases to 40-60 g-ds/d/PE.

In all cases the final cake solids concentration averaged 27%, mainly obtained through dewatering by centrifuge, beltpress and filterpress, while sludge thermal drying at solids concentration >70% was quite limited in 2005, covering only 2% of treated sludge, but an estimated increase to 30% in very few years, in parallel to a higher interest in energy reuse of residual sludge.

As far as stabilisation is concerned, anaerobic digestion was adopted in 70% of works, mainly due to advantages of biogas production and utilization.

As regards different options of disposal, landfilling is now reduced to 38% (in 1994 it was 80%) and will continue to decrease as a consequence of the more stringent European normative limiting organic wastes to landfill (Directive 1999/31/EC). About 55% of sludge finds material reuse through both direct agricultural utilization and, to a lesser extent, composting and land recovery, while thermally treated sludge amounts to only 6%. The remaining 1% is disposed of by other ways.

However above figures refer to 36 organizations for management of integrated water services serving a total of about 19 million PE mainly in Northern Italy (78%), where industrial contamination of wastewaters is higher, so landfilling is applied to a larger extent than in the rest of the Country. This can explain differences found in ONR (2006), where the whole of Italian territory is considered: figures show sludge landfilling reduced to 24%, and agricultural utilisation, including co-composting and land recovery uses, increased to 69%. About 2% is incinerated and 5% kept in temporary storage basins.

From the same Federutility survey, disposal costs of WTS (referred to a metric ton of wet sludge at around 25% dry solid content) are in the range of 45-90 €/t for utilization in agriculture (being 20-70 €/t average value for European Union countries), 60-90 €/t for composting (20-75 €/t), 85-220 €/t for thermal treatments (70-150 €/t), and 75-135 €/t (15-200 €/t) for landfilling. This clearly shows that costs are higher than average figures available for other European countries.

On the contrary, tariffs applied in Italy are much lower than those applied in the EU, as they average 0.27 €/m^3 of treated wastewater (average 0.56 €/m^3 in the EU), and 0.71 €/m^3 for the integrated water services (average 1.80 €/m^3 in the EU).

As far as other costs are concerned, 100 litres of diesel fuel at public pumps cost in the range of 125-130 €, of which 60 € are taxes; however, due to a reduced taxation, diesel fuel for agricultural services costs only 80 € per 100 litres. The cost of 1 kWh of electricity ranges 0.10-0.25 € per kWh, while for industrial contracts the overall cost (including the incidence of fixed costs which are related to the total installed power) ranges between 0.10 and 0.15 €/kWh, as electric energy is often supplied at a voltage of 15 kV.

TECHNOLOGIES AND SOLUTIONS

Technologies for WTS treatment and disposal

Treatment options

Sludge production can be reduced by 30 to 60% with one or a combination of more technological solutions (Bertanza *et al.*, 2004):

- apart from sludge retention time (SRT) control, other methods and technologies begin to be applied on the wastewater treatment stream in Italy, such as:
  - ozonation of a fraction of the recycle sludge stream (at few plants);
  - exposure of a fraction of the recycle sludge stream to micro-aerobic or anaerobic conditions after ultra-fine screening (currently under testing at one plant in Northern Italy);
- technologies that are usually applied to the sludge treatment stream:
  - thickening, either conventional or dynamical (centrifuges or belt thickeners);
  - aerobic stabilization;
  - anaerobic digestion (mesophilic or, in very few cases, thermophilic);

  - conditioning and mechanical dewatering;
  - thermal drying (applied to a number of WWTP in Italy since 20 years);
- technologies that have been more recently applied for the reduction of sludge production:
  - sludge lysis by thermal, mechanical (sonication, disgregation), chemical (ozone) or thermo-chemical (alkaline hydrolysis) methods;
  - wet-oxidation;
  - chemical oxidation by hydrogen peroxide.

Disposal options

Apart from direct agricultural utilisation, in Italy material recovery from WTS is implemented by combined composting that is performed by treating WTS with other organic fractions, such as the organic fraction of municipal solid wastes, wood chips from broken pallets, and cuttings from gardening and forest maintenance. When the quality of the compost is not high, mainly because of heavy metals exceeding the limits for unrestricted use, the resulting material can be used for land reclamation or landfill coverings. In some cases, WTS is added in small amounts (up to 5%) to lime and clay in thermal processes to produce inert materials, such as expanded clay for construction.

Adoption of sludge thermal treatment in Italy is low, and accounts as already stated for a mere 6% at most. Incineration or co-incineration with municipal solid wastes is the most common thermal sludge disposal route in Italy. Sludge pyrolysis with gasification is currently under evaluation by a few water service companies.

Current management practices

The main technical options for sludge treatment, disposal and reuse currently practiced in Italy are (i) sludge treatment within a single wastewater treatment plant, namely thickening, stabilisation, mechanical dewatering, and (ii) final disposal/reuse through spreading on agricultural soil, landfilling, thermal destruction with energy and material recovery (e.g.: in cement kilns dried sludge at 90% solids content is used as supplemental fuel and its ash used as mineral material).

Sludge post-treatments, such as hygienization and thermal drying, are seldom practiced. In all cases, current management practices are influenced by both sludge characteristics and plant size. According to the European Urban Wastewater Directive (91/271/EC), small WWTPs can be considered those not exceeding 2,000 PE. In Italy, small WWTPs usually treat domestic wastewater only, no primary sedimentation is usually provided and excess sludge is often already stabilized as deriving from extended aeration activated sludge processes. Alternatively, excess sludge is stabilized by separate aerobic digestion. Sludge is seldom treated on site, but is hauled to centralized plants for dewatering and final disposal or reuse.

In small to medium size plants (up to approx. 100,000 PE), anaerobic digesters are commonly used, and normally built to treat mixed primary and putrescible biological excess sludge.

However, in areas where eutrophication must be controlled, strict standards on nutrients require biological processes for nutrient removal, with long sludge retention times. Often, in these cases, primary settling is not present or it is by-passed to save internal organic carbon for denitrification. As a result, in these plants anaerobic digesters are no longer used and the sludge is stabilized aerobically. A typical example is the Milan Nosedo WWTP, serving over 1 million PE, that has been built without anaerobic digestion.

Thermal driers have seldom been used in medium-size WWTPs, as 100,000 PE is usually considered the minimum threshold for economic viability.

However, recent regulatory restrictions on disposal to agriculture are fostering this technology, as dried sludge can be used as alternative fuel in cement kilns or for energy recovery in waste-to-energy plants. Especially for large size WWTPs, thermal treatment of sludge (drying, pyrolysis with gasification, incineration with energy recovery), is currently considered a feasible solution, as agriculture and landfilling will be no longer be viable disposal routes within few years.

Typical sludge characteristics from domestic wastewater treatment in Northern Italy are shown in Table 1 (Romani and Beltarre, 2006), and in Sardinia Island, an Italian Region where all sewage sludge is used in agriculture, in Table 2 (Pisu *et al.*, 2006).

Table 1. Characteristics of sludge from domestic wastewater (Northern Italy); values refer to a 5-year (2001-2005) field scale experiments of agricultural use on rice

	Sludge Avg ± st.dev.	Limits for agricultural use*
Dry matter (-ds) at 105°C (%)	22.0 ± 0.6	—
Organic carbon of biological origin (%-ds)	34.4 ± 6.9	> 20
Kjeldahl Nitrogen (%-ds)	4.4 ± 0.7	> 1.5
Total Phosphorus (%-ds)	1.5 ± 0.7	> 0.4
Copper (mg/kg-ds)	362.2 ± 121.9	< 1000
Lead (mg/kg-ds)	106.2 ± 47.4	< 750
Cadmium (mg/kg-ds)	2.6 ± 2.2	< 20
Nickel (mg/kg-ds)	49.3 ± 6.2	< 300
Zinc (mg/kg-ds)	783.5 ± 276.6	< 2500
Chromium – total (mg/kg-ds)	106.5 ± 15.5	< 750
Chromium VI (mg/kg-ds)	0.0 ± 0.0	< 10
Mercury (mg/kg-ds)	2.0 ± 0.9	< 10
Arsenic (mg/kg-ds)	3.4 ± 2.0	< 10

**Note: Italian DL 99/1992, enforcing European Directive 86/278/EEC.*

Table 2. Average nutrient and heavy metals contents in sewage sludge used in agriculture in Sardinia during years 2005 and 2006 (Pisu et al., 2006)

	Total N (%-ds)	Total P (%-ds)	Cd	Cu	Ni	Pb	Zn	Hg	Cr
			(mg/kg-ds)						
2005	4.7	1.8	1.1	239.9	22.3	75.7	324	0.6	7.4
2006	5.2	1.4	1.6	260.7	15.6	76.2	577	0.2	22.3

It should be considered that sludge composition is highly variable in Italy because almost all WWTPs serve urban areas where industrial activities contribute to the organic pollution load. Further, many medium and large size plants are located in industrial districts, such as (i) the wool district (Biella, Piedmont), (ii) the silk district (Como, Lombardy), (iii) other textile finishing district (Prato, Tuscany), (iv) tannery districts in Veneto and Tuscany, (v) metal surface finishing districts in Piedmont and Lombardy, and other minor districts.

In such cases, obviously, sludge characteristics strongly depend on the influent industrial wastewater, as, for example, it carries many organic recalcitrant compounds that are absorbed by the sludge (such as hydrocarbons and LAS) and contain heavy metals, which usually precipitate as metal hydroxides during treatment and accumulate in the sludge.

It is also worth noting that sludge deriving from textile finishing districts has often poor dewatering characteristics: it is very hard to reach values higher than 22% solids concentration by centrifugation, while belt-presses hardly reach 17-18%.

WTS management strategies

Management strategies should consider either all the options that already exist in that area, or the need to develop further treatment/disposal/reuse options. These options should be evaluated considering the following aspects:

- land and urban planning;
- percentage of equivalent population (including industrial activities) sewered and served by wastewater treatment services, and its possible trend with time;
- the situation of the current existing technologies applied and need for their up-grading;
- regulatory development and trends;
- market and economic issues.

Three main management options can then be considered:

- all treatment, disposal and reuse options are managed by each Water Service Company; this can apply if the served area is very large (order of millions of PE served and thousands of square meters), with all options effectively located and managed within the corresponding area: this is not a current practice in Italy;
- treatment, disposal and reuse options can be managed jointly by Water Services and Municipal Solid Waste Services; as a matter of fact, in Northern Italy the integration of public services (energy, waste and water) is slowly progressing and could become a real possibility for the future; for example, this is the case of A2A (Milan and Brescia in Lombardy) and of Hera and Enìa (Emilia Romagna): this makes possible a practical implementation of co-management with municipal solid wastes, as discussed in more detail in Section 5;
- a third option is just to rely on the market, as disposal and reuse are contracted to bidders: this is at present the most common management option in Italy.

CO-MANAGEMENT WITH MUNICIPAL SOLID WASTES

The combined management of sewage sludge and municipal solid wastes should allow, in most cases, technical problems possibly deriving from their separate handling to be overcome, and significant economic advantages and environmental benefits to be consequently obtained.

Composting is the typical process in which the different characteristics of the wet fraction of solid wastes, and sewage sludge can be usefully integrated to obtain a final product of better quality, because the relatively higher solids content and C/N ratio of solid waste can counterbalance the lower solids concentration and C/N ratio of sludge.

In co-incineration, sludge drying can take place using the excess heat recovered from solid waste combustion, but greater attention in designing and operating furnaces and exhaust gas abatement systems should be required.

Co-landfilling of sewage sludge and the organic (wet) fraction of municipal solid wastes, when permitted by regulations, allows a faster stabilisation, a better leachate quality and a higher biogas production to be obtained, but the operating procedures must be carefully planned. However, such a combined management faces difficulties, mainly because each waste stream is often handled under different authorities, so they follow separate management routes. This problem also exists in Italy where, however, things are now changing."

In addition to what has been discussed in Sections 4.1.2 and 4.3, wastes treated in composting plants in 2005 amounted to about 3 million tons, with an increase of 125% with respect to 1999. Plant inflow consisted of 69.7% of organic fraction deriving from separate collection and green wastes, 15.7% of sludge (+6.8% with respect to 2004) and 15% of other organic wastes, mainly from the food industry.

Only recently, experiences for anaerobic co-digestion of sludge and wet fraction deriving from separate collection of municipal solid wastes started.

The most significant experience of this type is possibly that in Treviso applied to 3,500 t/y of solid waste wet fraction and 30,000 t/y of sewage sludge. In ONR (2006) information on co-digestion plants in operation is reported, which demonstrates a still marginal diffusion of this technology in Italy. Among co-digestion plants, those located in Cagliari (40,000 t/y of solid waste wet fraction and 15,000 t/y of sewage sludge), Camposampiero (12,000 t/y and 12,000 t/y, plus 25,000 t/y from zootechnical wastewaters), Bassano (16,000 t/y and 3,000 t/y), Viareggio (5,000 t/y and 50,000 t/y) can be mentioned.

The energetic valorisation of sludge in plants for combustion of solid wastes appears feasible and convenient if it is considered that the per capita production of sludge at 25-30% solids concentration is only 1/10 of that of municipal solid wastes, possibly reduced to less than 5% if a drying step for sludge is introduced.

An interesting experience on this method, serving an industrialised area, has been established in Sesto San Giovanni, near Milan, in cooperation with two public Companies formed by local Municipalities. One Company has responsibility of water services for 194 Municipalities in the Provinces of Milan, Lodi and Pavia, and operates the wastewater treatment plant in Sesto San Giovanni, serving 110.000 PE and producing about 3,300 t/y of sludge at 26% solids concentration. The other Company has responsibility for collection and disposal of solid waste in an area of 250,000 inhabitants, and operates the incineration plant in Sesto San Giovanni, treating about 70,000 t/y of waste and producing 36,000 MWh of electrical energy. Biogas of the wastewater treatment plant (about 750,000 m^3/y) is sufficient to dry sludge at 70-80% solids concentration. Presently, the plant has been authorised for experimental tests and results are encouraging. Total energy balance indicates that both plants are self-sustaining with a surplus of 22,000 MWh/y.

CASE STUDIES

Three case studies are discussed in this document, the first in Northern Italy (plant A), the others in Southern Italy (plant B and C).

Plant A

This plant treats urban wastewater, with more than 70% domestic origin, in an industrialized area in Northern Italy and has a design capacity of 130,000 PE, actually serving 110,000 PE.

After screening, degritting, and primary settling via a lamella clarifier, more than two-thirds of the flow rate are treated by submerged biofilters and one-third in a conventional activated sludge process. Water is discharged to a river after final disinfection with sodium hypochlorite. The tariff paid by users for wastewater treatment services is 0,275 €/m^3. This tariff does not include maintenance of sewers and water supply services, which are separately paid.

Typical influent and effluent values are reported in Table 3.

Table 3. Average influent and effluent concentrations for Plant A (in mg/l)

Year	BOD_5	COD	TSS	$N\text{-}NH_4^+$
Influent				
2006	190	348	177	21.7
2007	175	320	171	26.6
Effluent				
2006	14	42	14	3.1
2007	15	42	10	5.1

Sludge treatment includes pre-thickening (in: 12 kg-ds/m^3; out: 35 kg-ds/m^3), anaerobic digestion, post-digestion thickening and mechanical dewatering by centrifugation (in: 35-45 kg-ds/m^3, out: 260 kg-ds/m^3 = 26%). Anaerobic digestion allows the reduction of volatile solids to total solids ratio from 72% to 59%, with a retention time of 29 days and a VSS loading rate of 0.86 kg-SSV/m^3*d). Biogas production is about 2,200 m^3_n/d.

The total amount of dewatered sludge produced is 3,300 t/y (i.e. about 860 t-ds/y, corresponding to 30 kg-ds/y/PE). The total operational cost for sludge treatment ranges from 40 to 50 €/t, which, at 26% ds, means about 150-190 €/t-ds.

As the content of copper and zinc exceeds the limit for agricultural utilisation, the dewatered sludge is disposed of by landfilling at an additional cost of 132 €/t-wet sludge (i.e. about 508 €/t-ds). The average overall cost for electricity is 0.115 €/kWh.

Plants B and C

In Region Puglia (Apulia), Southern Italy, all wastewater treatment plants are run by Acquedotto Pugliese (AQP, Apulian Aqueduct), a public Company founded more than 100 years ago and almost totally owned by the Region. AQP manages the entire water integrated service from water collection to potabilisation, distribution, sewering, wastewater treatment, and sludge management.

General figures are: (i) 4,000,000 of population served, (ii) 15,891 km of potable water network, (iii) 9,550 km of sewerage, and (iv) 174 wastewater treatment plants, including 8 plants with only primary treatments, 7 with extended aeration, 68 with also tertiary ones, and 121 with nitrification-denitrification sections (Romano, 2008).

As far as residual sludge treatment and disposal are concerned, 96 plants include sludge aerobic stabilisation, and 43 anaerobic digestion. In 2006 more than 80,000 t have been directly utilised in agriculture, 31,322 t submitted to composting, and 2,215 disposed of in landfills.

The wastewater treatment plant in Barletta (Plant B) treats about 18,400 m^3/d deriving from 96,000 PE. The sludge line includes two-stage anaerobic digestion (2 primary digesters with connected boilers for sludge heating, and 1 secondary digester), post-thickening, mechanical dewatering by centrifuge, gasometer for storage of biogas used for heating sludge in digestion, and flare.

Sludge production in 2007 amounted to more than 5,000 t at a solids concentration of 24.5%. Composting is the management option adopted for this plant. Average main characteristics of above sludge are listed in the following Table 4.

Table 4. Characteristics of sludge from the municipal wastewater treatment plant in Barletta (Southern Italy) – Plant B (Romano, 2008)

	Average value	Limits for composting*
Dry matter (-ds) at 105°C (%)	24.5	-
pH	7.5	-
Organic carbon of biological origin (%-ds)	42.70	> 20
Kjeldahl Nitrogen (%-ds)	3.80	> 1.5
Total Phosphorus (%-ds)	1.85	> 0.4
Copper (mg/kg-ds)	330.80	< 1000
Lead (mg/kg-ds)	93.50	< 750
Cadmium (mg/kg-ds)	1.15	< 20
Nickel (mg/kg-ds)	22.70	< 300
Zinc (mg/kg-ds)	970.00	< 2500
Chromium – total (mg/kg-ds)	25.60	-
Mercury (mg/kg-ds)	0.30	< 10
Salmonella (MPN/g-ds)	absent	< 1000

**Note: Italian DL 99/1992, enforcing European Directive 86/278/EEC.*

The wastewater treatment plant in Giovinazzo (plant C) is a smaller treatment plant serving about 19,000 PE. The sludge line includes aerobic stabilisation, post-thickening, mechanical dewatering by centrifuge, emergency drying beds.

The production of sludge amounted in 2007 to about 480 t at an average solids concentration of 12%. About 76% of residual sludge is landfilled, while the remaining 24% is composted.

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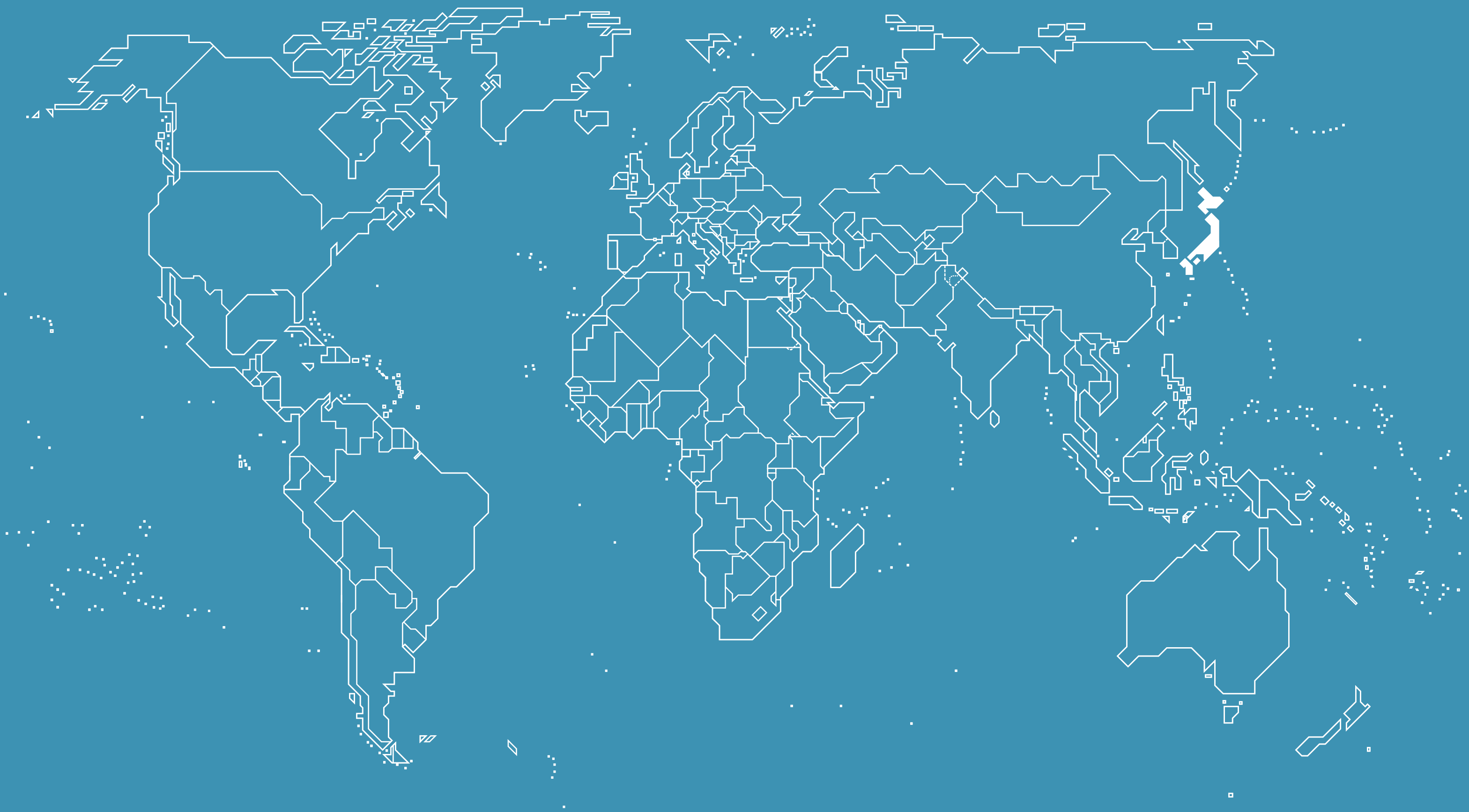


Japan

Japan: General

BASIC STRATEGY FOR SEWAGE SLUDGE RECYCLING IN JAPAN

The rising global demand for resources and energy has prompted international concern over dwindling resources and energy supplies. Japan, currently dependent on overseas markets for most of its resources and energy, needs to establish its own secure supply. Various environmental loads are also increasing, accompanying greater consumption of resources and energy. Global warming is the most evident example of the influence of increased environmental load, and effective countermeasures must be implemented around the world. To address these problems, it is essential to shift away from a "mass production, mass consumption, mass disposal" type of society toward a resource and energy recycling-oriented society.

In the course of establishing the resource and energy recycling system in Japan, the social focus has been on the municipal wastewater systems collecting vast amounts of wastewater that contain useful minerals and organic substances as well as heat energy. In other words, substances collected by sewerage have great potential as resources and energy that can be recycled and utilized.

Against this background, our objective is to convert from 20th-century type sewerage, which focused mainly on "development and expansion", to 21st-century type sewerage that creates "sound and effective water circulation and resource recycling". The concept of this type of sewerage was introduced in "Sewerage Vision 2100". One of its policies is opening "the way to resources" to help prevent global warming and achieve energy independence for wastewater treatment plants (WWTPs) by actively using the resource recovery and supply functions of sewerage, in addition to its usual functions, such as improvement of the water environment.

The following three approaches show different viewpoints on developing measures to open "the way to resources". "The way to resource independence" focuses on increasing the energy-independence rate of sewerage facilities; "the way to effective resource utilization" aims to supply new resources locally through the practical use of accumulated sewage sludge, available space and other local potential sources; and "the way to environment-friendly resources" is expected to contribute to environmental conservation and the prevention of global warming by using resources and energy produced by sewerage systems.

From these points of view, we have set three goals prior to developing concrete measures: "100% energy independence of WWTPs", "leading in practical uses for new energy" and "active supply of energy and resources to local areas". We aim to establish WWTPs that will not be dependent on conventional fossil fuels, but instead will use the energy contained in sewerage. To achieve this, energy saving in sewerage facilities is also important to eliminate dependence on limited resources and to control greenhouse gas emissions. Regarding leading in practical uses for new energy, we aim to carry out programs that will allow us to pioneer the use of new forms of energy extracted from biomass such as kitchen garbage, pruning waste and domestic animal excrement, in addition to sewage sludge, through further upgrading and efficiency improvement of the digestion gas refining process that has long been successful, and by using the sewer pipe networks that extend throughout our cities.

Concerning the active supply of energy and resources to local areas, the vulnerability of fossil fuel supplies has raised the serious issue of maintaining energy supplies in local areas. Since it is also crucial to prevent global warming, we aim to contribute by supplying local areas with resources and new energy created in the WWTPs as the core basis for local areas.

PRESENT STATE OF SLUDGE TREATMENT IN JAPAN

Sewage works in Japan have expanded due to the construction of wastewater treatment plants, and the installation of sewer pipes has progressed simultaneously. As a result, all sewage treatment facilities in Japan have adopted secondary treatment systems. Since achieving 70.5% in FY 2006, the percentage of sewered population in Japan has grown to reach one of the highest levels in the world.

The quantity of sewage sludge generated from the biological sewage treatment processes has steadily increased in line with the development of sludge, and over 2 million tons as dry solid is now being generated per year. So far, the main purposes of sludge treatment have been stabilization and reduction of volume. In the process of sludge stabilization, easily degradable organic substances are decomposed, and the generation of odors and proliferation of harmful insects are strictly controlled. This is done by anaerobic digestion and composting. The sludge volume reduction process involves decomposing organic substances in order to maintain space at the final disposal sites. A typical form of sludge reduction is incineration treatment. At present, about 70% of sludge is incinerated after being thickened and dewatered.

Recent sludge treatment plants include the beneficial use of sludge treatment. Since the 1990s, tremendous progress has been made in using treated sludge as construction material, particularly recycling sludge as a material for cement. The application of incineration treatment for sludge has advanced, mainly in city areas, where the utilization of inorganic substances in sludge has been progressing. On the one hand, the recycling of sludge as a resource for cement material is limited from the viewpoint of sludge transportation; on the other, the beneficial use of sludge tends to depend too much on the cement plant in some cities, where diversification of beneficial uses for sludge is considered to be a critical issue for risk management.

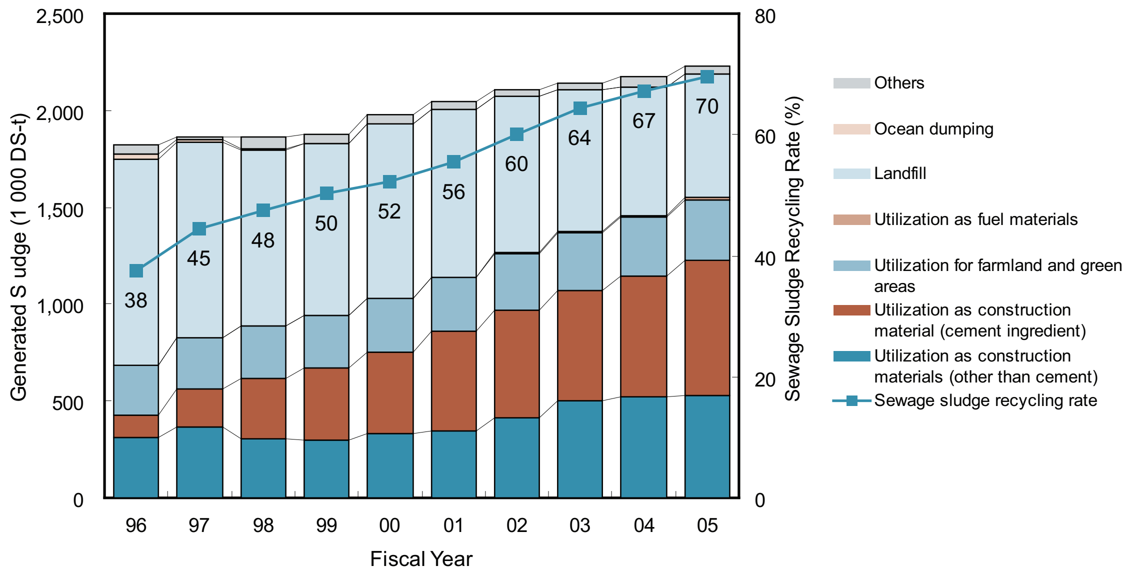
PRESENT STATE OF BENEFICIAL USE OF SEWAGE SLUDGE IN JAPAN

The beneficial use of treated sewage sludge has gradually increased to over 60%, and the rate of utilization of treated sludge for farmland and green areas has been fairly stable at around 14% for many years (Figure 1). While this rate is expected to be maintained in the future, recent technical development has facilitated the recovery of phosphorus from sludge, and the cultivation of new fields for using the phosphorus in treated sludge is promising. In addition to recycling sludge as cement material, its use as a construction material has been boosted by the development of a sludge melting treatment. Melt-solidified slag, a highly safe recycled material, can be used as backfill and sub-base course material. Standardization of melt-solidified slag obtained from sewage sludge and municipal solid waste was attained for concrete aggregate. This standardization is expected to accelerate the use of melt-solidified slag produced from sewage sludge.

Anaerobic digestion to recover energy from sludge has been reconsidered as a measure to control global warming effects. Digestion gas is being used to heat digestion tanks and as supplementary fuel for incineration furnaces. Progress is also being made in the program for generating power using digestion gas as fuel. In addition, the development of fuel from sludge is attracting attention as a new energy form that can be substituted for fossil fuel. The use of organic substances in sludge, and the carbonization and drying of sludge are being studied in relation to the local conditions of potential users such as coal thermal power generation plants.

In order to promote sludge utilization, information exchange and educational campaigns are important. For example, the Japan Sewage Works Association (JSWA) encourages the use of sewage sludge through a wide range of activities, including producing manuals, publishing the informative magazine “Recycling and Use of Sewage Sludge” and hosting seminars, as well as cooperating with municipalities, concerned companies and users. For producing the manuals, the JSWA established a committee consisting of government and municipal representatives and academic experts in the field, with the results of long-term discussions being incorporated into the manuals. The 2001 edition of the “Manual for the Use of Sewage Sludge as Construction Material” presents standards for using incineration ash as soil improvement material, concrete products such as interlocking blocks, baked products such as bricks, and asphalt fillers, and gives example applications along with marketing strategies. The 2005 edition of the “Manual for the Use of Sewage Sludge in Farming and Greening” describes product quality control, effects of application and application standards for various farm products, as well as new technologies such as carbonized sludge and sewage sludge compost integrating other organic matter (such as garbage, stockbreeding waste) and MAP (magnesium ammonium phosphate).

Figure 1. Amount of generated sewage sludge and its beneficial use in Japan



TECHNOLOGY DEVELOPMENT – LOTUS PROJECT

In March 2002, the Ministry of Land, Infrastructure and Transport (MLIT) implemented SPIRIT21 (Sewage Project, Integrated and Revolutionary Technology for 21st Century), a new technology development project, with the cooperation of the private sector, academic institutes and municipalities. Under the framework of SPIRIT21, the MLIT is promoting LOTUS (Lead to Outstanding Technology for Utilization of Sludge), a project on sewage sludge recycling. The research period for the LOTUS Project is 4 years, from FY 2005 to 2008.

In regard to sewage sludge recycling, the increased cost of recycling, in addition to the need to save energy and the shortage of industrial waste disposal sites, has become a serious issue. The technologies being studied for development in the LOTUS Project are classified into the following two types:

1. Technology for recycling the total quantity of sewage sludge at a lower cost than that for disposing of sewage sludge (sludge zero discharge technology)
2. Technology for generating electric power at a lower cost than that for purchasing electric power, by utilizing biomass such as sewage sludge (green sludge energy technology)

The distinctive feature of this project is that it is the first to set cost as a development goal in addition to the previous goal of performance. Research and development, and the introduction of an inexpensive system combining various elementary technologies, is being accomplished, adapting to the severe financial circumstances of sewerage management.

1. Sludge zero discharge technology:
   - Production of biosolid fuel from sewage sludge
   - Technology for recovery of phosphorus from incinerator ash

- Production of activated carbon from sewage sludge and reduction of sludge treatment cost by beneficial utilization

2. Green sludge energy technology
   - Energy recovery from sewage sludge and biomass with synchronous digestion
   - Anaerobic co-digestion system for power generation with low running cost
   - Sludge reduction through accelerating digestion and electric power generation system using digestion gas
3. Dual technology integrated development
   - Methane fermentation system for sewage sludge and raw garbage, and carbonization-activation for utilization

FUTURE DEVELOPMENT

The connection between beneficial utilization of sludge and sludge treatment has become much closer. In the future, all sludge treatment will be carried out taking into account the beneficial utilization of sludge from the viewpoint of users. In addition to the example of recycling sludge as fuel through carbonization, a new project has been launched for refining digestion gas to produce fuel for natural-gas motor vehicles. Accompanying such programs for creating energy through extensive use of sludge, energy-saving is needed in the sewage treatment itself, including sludge treatment.

Meanwhile, the initiative on redefining wastewater treatment plants as the core of local biomass utilization has been incorporated in several cities. This initiative aims for large-area optimization of energy utilization making use of sewerage facilities, recognizing that a sewerage system is a local asset. When biomass such as garbage, vegetation and other local organic waste material is accepted and fermented together with sewage sludge, the increased amount of digestion gas will be beneficially utilized. Furthermore, by means of natural energy additionally developed, wastewater treatment plants could attain rational energy independence.

CASE STUDIES INTRODUCED IN THIS ATLAS

This atlas introduces six case studies illustrating the positive environmental contribution made by improving the treatment efficiency and promoting the beneficial use of sewage sludge (Figure 2).

The Tokyo Metropolitan Government has been tackling the problems of reusing sludge, in particular the carbonized material produced from dewatered sludge that is utilized at coal fired power generation plants. In Sapporo City, in the northern part of Japan, a proportion of the sludge has been composted since 1984 and utilized for green areas and agricultural land. But the city faces difficulties with the maintenance and operational costs necessary to continue sludge composting. In Yokohama City, two centralized sludge treatment and recycling centers are responsible for finding effective uses for sludge as a resource rather than disposing of it in landfill. There have been attempts to develop soil-improving ash as well as to recycle the ash for use in construction material. In Osaka City, a major proportion of the sludge is treated using the thermophilic high concentration digestion process. Final sludge treatment is incineration and/or melting. Part of the incineration ash is recycled as material for blocks and the slag produced by melting is used in construction materials. In Kobe City, sludge from wastewater treatment undergoes digestion treatment and dewatering. A unique Kobe Biogas project to refine digestion gas which can then be used in natural gas vehicles has started as a highly interesting option to reduce CO_2 emission from fossil fuels. The above cities have populations in the millions. But Suzu City has a small population of less than 20,000. Mixed sludge composed of sewage sludge, other kinds of wastewater sludge and garbage has been treated by mixed methane fermentation, and the residue after treatment has been dried and used in agriculture and forestry. Thus, Japan is tackling the problem of developing sustainable wastewater biosolids.

Figure 2. Sewage works administrators introduced in this atlas

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Outline of wastewater treatment in Kobe

KOBE CITY

The center of Kobe City, marked by the city hall, is located at latitude 34°41'24''N and longitude 135°11'44''E. The city covers an area of 552.72 km^2, stretching 36.1 km east to west, and 29.7 km north to south. Located in the Seto Inland Sea climate zone, the city enjoys a generally mild climate with many sunny days and little rain (mean annual rainfall of 1264.7 mm) in Japan, with four seasons and a mean annual temperature of 16.5°C. In Kobe, industries developed based on the port, particularly in port-related industries, such as trading, marine transportation, warehousing and shipbuilding.

Kobe City was hit by the Great Hanshin-Awaji Earthquake (M7.3) on January 17, 1995. This caused an outward shift of the city's population, which fell from 1.52 million before the earthquake to about 1.42 million by October 1995. However, following recovery from the earthquake, the population had returned to 1.52 million by 2004.

SEWAGE WORKS IN KOBE

Full-scale construction of the sewage system in Kobe City started in 1951. The city employs separate treatment of sanitary sewage and stormwater (except at the Higashinada Wastewater Treatment Plant, where combined treatment is partially used).

By the end of FY2006, the service area amounted to 18,586.1 ha, and the proportion of population served by sewers reached 98.5% (covering 1,504,413 people). Kobe City has seven wastewater treatment plants. Sludge from wastewater treatment undergoes digestion treatment and dewatering. The dewatered sludge from each wastewater treatment plant is delivered by truck to a sludge incineration plant (Tobu Sludge Center), where all the sludge is incinerated in a fluidized bed incinerator. Table 1 shows the wastewater input and dewatered sludge output at each wastewater treatment plant.

Table 1. Wastewater input and sludge output at each wastewater treatment plant (FY2006)

Treatment plant	Present population in the service area	Wastewater input (m^3)	Dewatered sludge cake output (ton)
Higashinada	372,728	58,445,526	30,412
Port Island	14,508	3,344,396	(sludge treatment at Higashinada)
Suzurandai	81,687	6,027,330	(sludge treatment at Seibu)
Chubu	(included in Seibu)	17,635,558	1,065
Seibu	358,508	41,732,785	25,908
Tarumi	317,657	36,083,949	14,273
Tamatu	217,550	26,393,552	11,465
Total	1,362,638	189,663,096	83,123

OUTLINE OF SLUDGE TREATMENT IN KOBE (DIGESTION TREATMENT)

Kobe City annually treats about 190 million m^3 of wastewater, producing some 1.1 million m^3 of sludge. The sludge from wastewater treatment plants, after thickening, undergoes anaerobic digestion treatment to reduce the volume and stabilize the quality.

The digestion treatment consists of loading sewage sludge into digestion tanks at treatment plants and decomposing it over a period of 20 to 25 days by the action of microbes (anaerobic bacteria) at an elevated temperature of about 39°C. In this process, digestion gas, mainly methane, is generated.

In Kobe City, the digestion gas generated from this process is effectively used at each wastewater treatment plant, for heating the digestion tanks and for space heating/cooling at the office. The unused excess digestion gas is disposed of by incineration.

In FY2006, the total amount of digestion gas generated by the city amounted to 10.3 million Nm^3, of which 5.5 million Nm^3 (about 54%) was used effectively. Table 2 shows the digestion gas output and amount used at each wastewater treatment plant. By calorific value, 1 Nm^3 of digestion gas is equivalent to about 0.7 L of heavy oil.

We also recently started a unique Kobe Biogas (hereinafter called Biogas) project for refined digestion gas that can be used by natural gas vehicles.

The next section describes the Kobe Biogas (Biogas), a new project of Kobe City for making even greater use of digestion gas.

Table 2. Digestion gas output at each wastewater treatment plant (FY2006)

Treatment plant	Digestion gas output (m^3)	Effective use			Amount used (m^3)	Usage rate (%)
		Digestion tank heating boiler (m^3)	Water heating and air conditioning (m^3)	Biogas (m^3)		
Higashinada	2,330,105	969,638	205,285	116,813	1,291,736	55.4
Chubu	614,563	336,666	138,538	-	475,204	77.3
Seibu	3,764,543	2,233,147	22,575	-	2,255,722	59.9
Tarumi	1,990,049	697,272	201,739	-	899,011	45.2
Tamatu	1,574,075	528,170	74,487	-	602,657	38.3
Total	10,273,335	4,764,893	642,624	116,813	5,524,330	53.8

EFFECTIVE USE OF DIGESTION GAS BY THE KOBE BIOGAS PROJECT

Background of using digestion gas as vehicle fuel

The Kobe City's Higashinada Wastewater Treatment Plant was damaged by the Great Hanshin-Awaji Earthquake, and the wastewater treatment facility was out of action for 100 days. Restoration of the badly damaged wastewater treatment facility and other facilities was completed by the end of FY1998. Reconstruction of the sludge digestion tanks was then started in FY1999 following the discovery of damage to their foundation piles. Kobe City took the opportunity of this reconstruction and renewal project to examine the possibility of effective use of the digestion gas.

Since the Higashinada Wastewater Treatment Plant used the waste-generated power from the nearby Higashi Clean Center (municipal waste incineration plant), it was not necessary to consider running gas engine generators by digestion gas, so the city conducted experiments on refining digestion gas into almost pure methane, which can be used as vehicle fuel. (Kobe City carried out a joint research project with the Public Works Research Institute and a private company from FY2005 to FY2006).

Demonstration experiment of biogas refining system

Digestion gas consists of approximately 60% methane and 40% carbon dioxide, and trace amounts of such substances as hydrogen sulfide and siloxane. To be able to use the digestion gas as vehicle fuel, it was necessary to: (1) remove carbon dioxide to increase the concentration of methane, making the product equivalent to city gas (natural gas) in terms of energy; and (2) remove impurities such as hydrogen sulfide and siloxane (a silicon compound used in shampoo and cosmetics), which causes problems for vehicle engines.

The conventional desulfurization process, however, could not remove impurities other than hydrogen sulfide, so we developed a water scrubbing method for refining the digestion gas. This method removes impurities by taking advantage of the solubility of carbon dioxide and hydrogen sulfide into water under high pressure. At the plant, the digestion gas pressurized to 0.9 MPa (approx. 9 times atmospheric pressure) is brought into contact with treated wastewater inside a scrubber, to increase the methane concentration and remove the impurities. Figure 1 shows the refining system and the water scrubbing process flow.

Figure 1. Refining system and the water scrubbing process flow

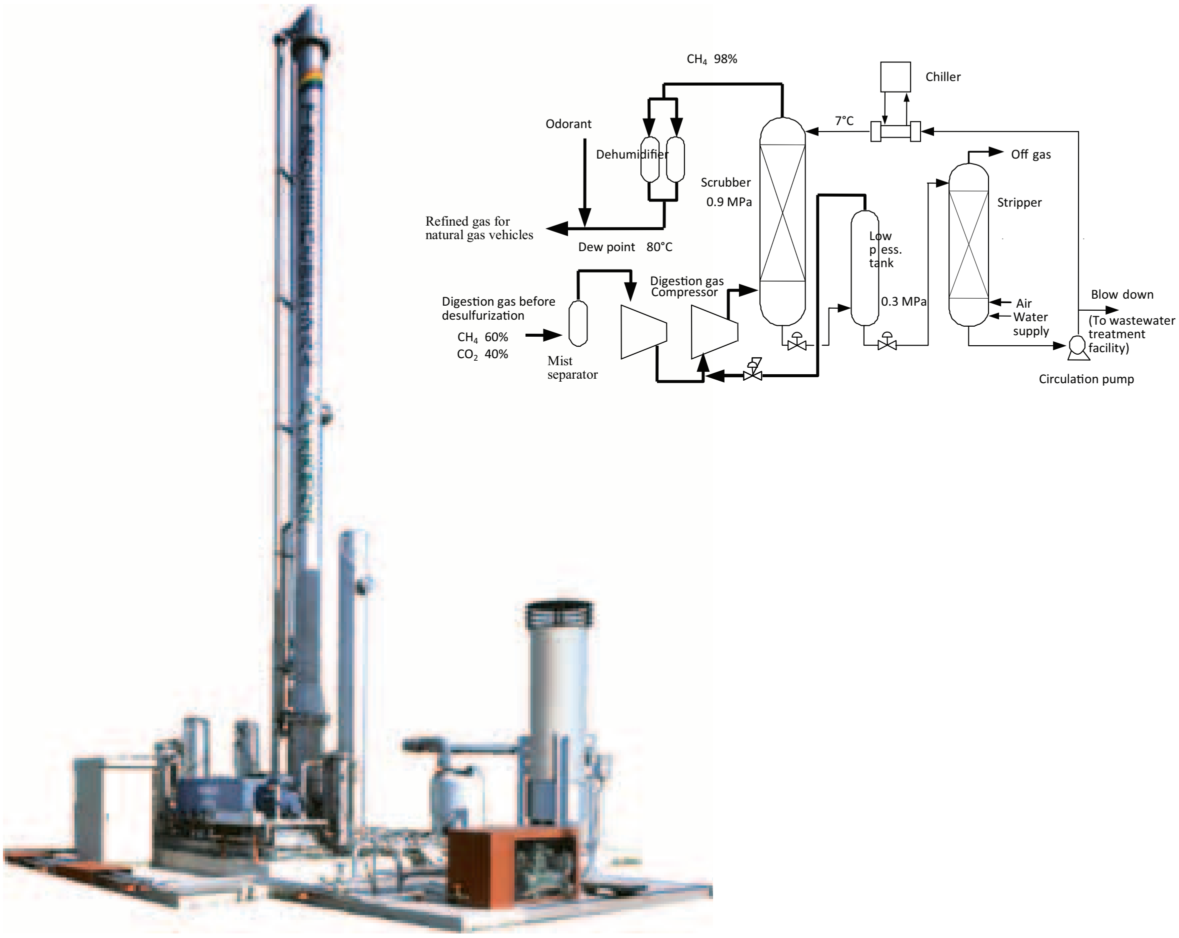


Photo courtesy of the authors.

The pilot plant demonstrated that the water scrubbing method could increase the methane concentration in the refined gas to approximately 98% and remove impurities such as hydrogen sulfide and siloxane. Table 3 shows the digestion gas and refined gas composition.

Table 3. Digestion gas and refined gas composition

	CH_4 [%]	CO_2 [%]	O_2 [%]	N_2 [%]	H_2S [ppm]	Siloxane (D5)*[1] [ppm]	Higher calorific value (calculated)	
							MJ/Nm³	kcal/Nm³
Digestion gas	59.9	37.0	0.4	0.8	330	24	23.9	5,720
Refined gas	98.2	0.6	0.2	1.0	<0.1	<0.005	39.2	9,370

*[1] *An example of siloxane constitutional formula*

Evaluation of biogas as vehicle fuel

To evaluate the suitability of Biogas as vehicle fuel, we performed the following tests: (1) exhaust gas test, (2) engine output test and (3) vehicle traveling test (fuel consumption and travel performance), using Biogas 100%, Biogas 50%, and city gas 13A as fuel.

Exhaust gas test

We tested the exhaust gas and engine output at automobile inspection institutions using existing models of natural gas vehicles (standard-sized car and large-sized bus).

For each type of vehicles, the tests demonstrated that Biogas, like city gas, would comply with the emission control criteria. Tables 4 and 5 show the results of the exhaust gas test.

Table 4. Exhaust gas test results for standard-sized car (unit: g/km)

Exhaust gas component	Fuel	Exhaust level	Emission control levels for 2006		Certified emission level of the tested vehicle model
			Highest	Lowest	
CO	Biogas 100%	0.089	1.92	1.15	1.15
	Biogas 50%	0.108			
	City gas 13A	0.121			
NMHC (non-methane hydrocarbons)	Biogas 100%	0.0007	0.08	0.05	0.013
	Biogas 50%	0.0008			
	City gas 13A	0.0028			
NOx	Biogas 100%	0.0073	0.08	0.05	0.013
	Biogas 50%	0.0067			
	City gas 13A	0.0084			

Tested at: Japan Automobile Transport Technology Association (JATA), Kansai Branch (Kyoto City)
Tested vehicle: total engine displacement 1.496 L, gross vehicle weight 1,665 kg
Emission level certified by the Ministry of Land, Infrastructure, Transport and Tourism: SU-LEV (75% reduction from 2006 standard emission level)
Test method: 10/15 + 11 modes

Table 5. Exhaust gas test results for large-sized bus (unit: g/kWh)

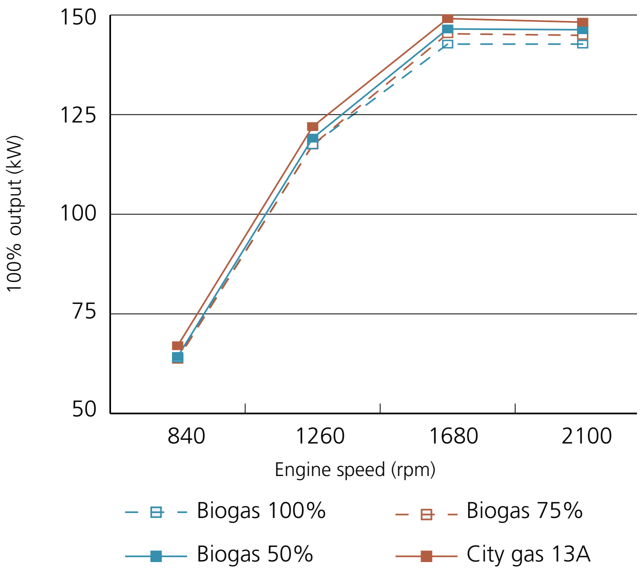
Exhaust gas component	Fuel	Exhaust level	1997 guideline
CO	Biogas 100%	0.04	102
	Biogas 75%	0.04	
	Biogas 50%	0.05	
	City gas 13A	0.04	
THC (total hydrocarbons)	Biogas 100%	3.37	6.2
	Biogas 75%	2.75	
	Biogas 50%	2.72	
	City gas 13A	1.81	
NOx	Biogas 100%	1.15	3.6
	Biogas 75%	1.15	
	Biogas 50%	1.33	
	City gas 13A	1.47	

Tested at: Nissan Diesel Research Development Corp. (Ageo City, Saitama)
Tested vehicle: total engine displacement 12.088 L
Tested vehicle's exhaust gas level: in compliance with the technical guideline for 1997
Test period: December 1 to 8, 2006

Engine output test

In the engine output test, Biogas again performed similarly to city gas. Figure 2 shows the results of the engine output test.

Figure 2. Engine output test results (large-sized bus)



Tested at: Nissan Diesel Research Development Corp. (Ageo City, Saitama)

Tested vehicle: total engine displacement 12.088 L

Tested vehicle's exhaust gas level: in compliance with the technical guideline for 1997

Test method: G13 mode

Test period: December 6 to 8, 2004

Vehicle traveling test (fuel consumption and travel performance)

In the vehicle traveling test, we used Biogas as fuel for a natural gas vehicle, and determined the fuel consumption and travel performance. In terms of the fuel consumption in actual driving, Biogas again performed similarly to city gas. In the loaded traveling test, which we performed to determine the travel performance, Biogas differed little from city gas. Tables 6 and 7 show the results of the two tests.

Table 6. Comparative evaluation of fuel consumption by a road maintenance patrol vehicle (actual measurement between April and August, 2006)

Tested vehicle (Biogas fueled vehicle)			Comparative vehicle (City gas fueled vehicle)		
Gas charge (Nm^3)	Travel distance (km)	Mileage (km/Nm^3)	Gas charge (Nm^3)	Travel distance (km)	Mileage (km/Nm^3)
1,192.3	7,653	6.4	625.3	4,423	7.1

Table 7. Loaded traveling performance (speed) of city bus

Biogas [km/h]	City gas [km/h]	Comparison with city gas
28.0	28.75	97.4%

Loading: about 1,600 kg (equivalent to about 29 persons onboard). The speed shown above is the average of speeds measured at 10 points.

Quality control criteria for biogas

As mentioned above, we succeeded in stably producing highly concentrated methane by refining the digestion gas by the water scrub bing method and gathered research data from the vehicle traveling test, exhaust gas test, and so on. Based on these results, we evaluated that Biogas can be used as vehicle fuel. However, like city gas, Biogas is regulated by the High Pressure Gas Safety Law and similar laws when actually used as fuel. To ensure compliance with these laws and be ready to supply Biogas of stable quality to users, Kobe City established quality control criteria (Table 8). The values given for moisture, sulfides, oxygen and siloxane are the control criteria for these substances in the gaseous state at the refining system outlet, while the criterion on odor applies to the time when the gas is charged into vehicles.

Table 8. Quality control criteria for biogas

Item	Description and applicable law/guideline	Biogas quality control criteria
Moisture	The amount present must not damage the container. (General High Pressure Gas Safety Regulation; Article 7, Paragraph 3, Item 3)	Dew point: -51°C or lower
	The dew point of the moisture content of the gas at the maximum service pressure of vehicles fuel containers (19.6 MPa by gage pressure) should be equal to or lower than the monthly minimum temperature minus 5.6°C. (The Japan Gas Association (JGA) guideline (NGV05-96) on the moisture content of natural gas used as vehicles fuel)	
Sulfides	The amount present must not damage the container. (General High Pressure Gas Safety Regulation; Article 7, Paragraph 3, Item 3)	Hydrogen sulfide: 0.1 ppm or less
Oxygen	The oxygen content must be less than 4% by volume. (General High Pressure Gas Safety Regulation; Article 6, Paragraph 2, Item 1, c. (a))	Methane concentration: 97% or higher Oxygen concentration: less than 4%
Siloxane	-	1 mg/Nm^3 or less (total of D3 through D6)
Odor	The gas must be detectable by smell when its concentration in the atmosphere is 1/1000 by volume. (General High Pressure Gas Safety Regulation; Article 7, Paragraph 3, Item 2, b.)	The gas must be detectable by smell when its concentration in the atmosphere is 1/2000 by volume.

CONCLUSION

After completing the various tests mentioned above, Kobe City started trials on using Biogas as fuel for public transport vehicles such as city buses. The city started to construct a production-scale refining system, gas tank and distribution system in FY2007, and these entered full-scale operation in February 2008.

The daily output of Kobe Biogas from the refining system is 5,000 Nm^3, of which 3,000 Nm^3 is consumed at the wastewater treatment plant. Once the distribution starts, Kobe City plans to use the remaining 2,000 Nm^3 per day as fuel for natural gas powered public transport vehicles. This amount is sufficient for 40 city buses to travel 50 km a day.

This usage of Biogas reduces CO_2 emissions from fossil fuels. Kobe City intends to continue projects like to use untapped energy resources at wastewater treatment plants, thus helping to curb global warming and create a sustainable recycling society.

ECONOMIC INFORMATION

The wastewater treatment cost in Kobe City was 21,513 million yen for 190 million m^3 of waste water (FY2006). 93.6 % of the cost is for operating wastewater treatment plants, including water treatment and sludge treatment (thickening, digestion, dewatering). The remainder (6.4 %) is for sludge incineration and disposal.

- Diesel fuel (heavy oil A): 75.2 yen/L
- City gas (13A): 152 yen/ Nm^3
- Electricity: 11.3 yen / kWh
- The sewer service charge in Kobe City is shown below.

Table 9. Sewer service charge in Kobe City (monthly charge per household)

Wastewater type	Water consumption		Amount (yen)
General sewage	Base charge	For up to 10 m^3	470
	Surcharge (per 1 m^3)	Above 10 m^3 and up to 30 m^3	98
		Above 30 m^3 and up to 50 m^3	128
		Above 50 m^3 and up to 100 m^3	152
		Above 100 m^3 and up to 200 m^3	183
		Above 200 m^3 and up to 500 m^3	215
		Above 500 m^3 and up to 1000 m^3	230
		Above 1000 m^3 and up to 2000 m^3	245
		Above 2000 m^3	260

Sewage sludge disposal and beneficial recycling in Osaka City

BACKGROUND

Osaka City and its sewerage system

Osaka City is located almost in the middle of the long chain of islands that form Japan. It has a population of 2,600,000 (day population: 4,000,000) and is one of the largest cities in Western Japan, with an area of 220 km^2. In ancient times, between the 5th and 8th centuries, Osaka occupied an important position for both overland and water transportation, and at one time served as the capital of Japan. Since the 16th century, Osaka has flourished as a center of economy and commerce, taking advantage of the development of a physical distribution system based on transportation using the many rivers. Even now, Osaka is known as *Mizu no miyako* (City of Water) after its many rivers and waterways that remain to this day. In the latter half of the 19th century, commerce and industry in Osaka developed rapidly.

The foundation of the urban area of the present Osaka City was formed around 1580. The roads were laid out in blocks like a checkerboard. In conjunction with the road construction, the prototype ditches of the present sewer system were constructed and connected to the waterways. Some of these sewage channels were rehabilitated and are still in use today.

Modernization of the sewerage system in Osaka City started in 1894, and the first sewage treatment plants at Tsumori and Ebie came into operation in 1940. Later, Osaka City rapidly expanded its sewage treatment capacity to deal with the environmental pollution that had become a serious problem in the high economic growth period. Up to the present, 12 sewage treatment plants have been constructed, and these have adopted the conventional activated sludge process or the anaerobic-oxic activated sludge process. The average volume of treated wastewater is about 1,800,000 m^3/day, and the volume of sludge generated (dry weight) is about 110 t/day (average in 2006). Sewage coverage ratio is now 100% of the population, and the total length of sewage pipes has reached 4,850 km.

Osaka City's distinctive approach to sludge digestion

Sewage treatment in Osaka City started in 1940. In the beginning, the liquid sewage sludge generated was just dumped into the ocean without being treated. However, since the problem of ocean pollution emerged, anaerobic treatment in a digestion tank and mechanical dehydration were introduced around 1960, and dewatered sludge began to be disposed of in landfill sites. The digestion gas produced in the anaerobic digestion process was used as the auxiliary fuel to heat the digestion tank. Sludge incineration started around 1970, aiming at further reduction of the sludge volume, where the digestion gas is also used as the fuel.

Thereafter, the volume of liquid sludge increased due to a deterioration of the sludge consolidation feature along with the alteration of sludge properties such as a decrease in sand and an increase in organic substances contained in the sludge, stemming from lifestyle changes and the advance of urbanization. This has consequently caused a decrease in the retention time of the sludge in the digestion tank, and an increase in the energy needed to heat the digester.

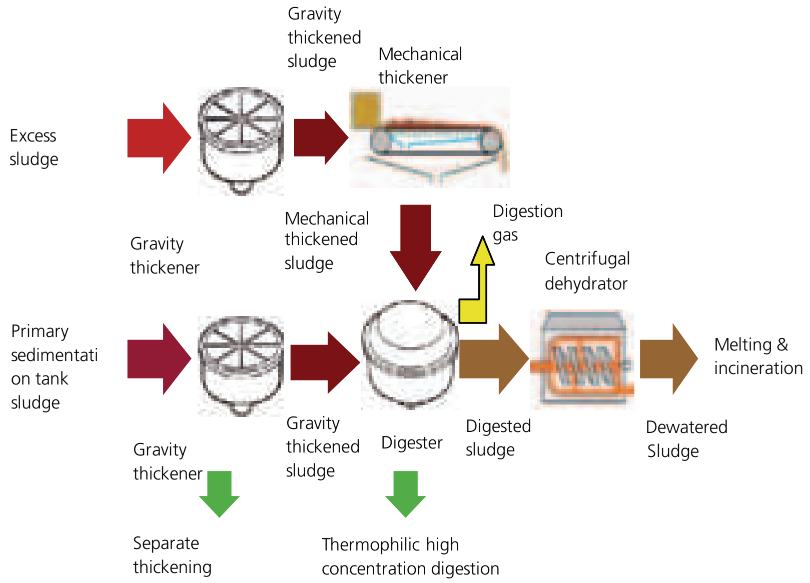
In order to solve this problem, a comprehensive review of the sludge treatment system was carried out in the 1970's and "high concentration digestion" adopting an improved thickening process was established. In the conventional thickening process, both the sludge from the primary settling tank and the excess sludge from the final settling tank were mixed and settled in the gravity thickener. On the other hand, in the newly developed process, two sludges are thickened separately; that is, the sludge of the primary settling tank is thickened by gravity, and excess sludge from the final settling tank is thickened in two stages: gravity thickening and mechanical thickening. Then the two sludges thickened independently are mixed and fed into the digester.

Introduction of a mechanical thickener in addition to the gravity thickening in this way increased the concentration of the thickened sludge from 2-3% before to 4-5%, resulting in a reduction in the volume of sludge fed to the digestion tank. This also allowed sufficient retention time for the sludge, and reduced the fuel requirement for heating the digestion tank. Accordingly, the digestion gas produced alone came to cover all the energy needed for heating the digestion tank.

However, after a full-scale high concentration digestion process was started in 1983, the problem of foaming occurred in the digestion tank due to the high viscosity of the sludge, which is detrimental to its steady operation. In order to solve this problem, the viscosity of the sludge was lowered by raising the digestion temperature from 35°C to 52°C (thermophilic digestion). This allowed the digestion gas generated in the process to be easily liberated from the sludge phase, and the foaming problem was successfully suppressed. In addition, a high temperature accelerates the digestion reaction and the conversion ratio of sludge to digestion gas was boosted by around 10%-15% from 45% to 55-60%, resulting in a reduction in the generation of dewatered sludge. Furthermore, the required capacity of the digestion tank can be minimized because the digestion reaction proceeds more quickly at a high temperature which permits a shorter retention period.

Following these developments, a fully-fledged thermophilic high concentration digestion process was launched in 1993. As a result, the total volume of sludge generated has decreased, and this could drastically cut the auxiliary fuel as a combustion aid, and also minimize the required capacity for incinerators. In Osaka City, the major portion of generated sludge is now treated through this thermophilic high concentration digestion process, and the facility is now being upgraded so that it can treat the remaining portion of the generated sludge by that process.

Figure 1. Thermophilic high concentration digestion process



Centralized sludge treatment system

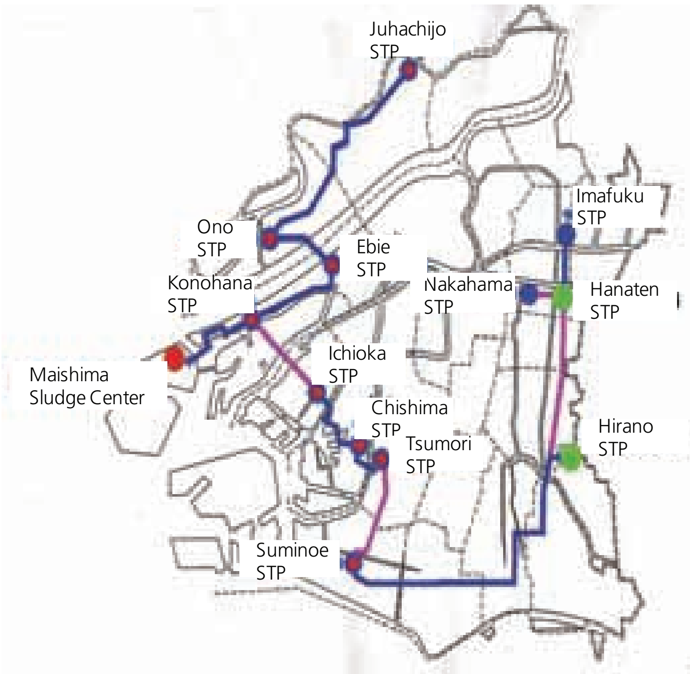
Osaka City is promoting a project to centralize sludge treatment in conjunction with the timing of the rehabilitation and renewal of superannuated incinerators in order to establish an efficient and upgraded sludge treatment system.

In this project, the new Maishima Sludge Center (MSC) was built on one block of an artificial island created by landfill (Fig. 2). The thermophilic high concentration digested sludge from eight sewage treatment plants (STPs) located close to the seafront area is pumped and send to MSC via a piping network that connects the STPs and MSC (Fig. 3), and collected sludge is subjected to treatment in one place. The sludge from the other four sewage treatment plants located in inland areas is piped to the Hirano Sewage Treatment Plant, where comprehensive treatment of the sludge is carried out in the same way.

Figure 2. Overall view of MSC

Photo courtesy of the authors.

Figure 3. Map of the sludge transportation network



SELECTION OF DISPOSAL PRACTICE

In 2006, the sewage treatment process in Osaka City produced 68,000 dry tons of sludge. However, 27,000 dry tons of the sludge was converted into digestion gas through the thermophilic high concentration anaerobic digestion process, and so the final volume of sludge generated was reduced to 41,000 dry tons.

Osaka City adopts two options for final sludge disposal. One is combustion of sludge in an incinerator, with the generated incineration ash being disposed of in a landfill site. The incineration ash can be recycled as construction material such as water permeable bricks after it has been sintered. The other option is to treat the sludge at a temperature of over 1,200°C, which is higher than that of incineration, and a reduction in the sludge volume can subsequently be achieved by producing vitreous melted slag.

In 2006, 60% of the generated sludge was treated by incineration and 40% was treated by the melting process. However, as the project for the centralization of sludge treatment continued, superannuated incinerators have been replaced by melting furnaces, and therefore 60% of the sludge was forecast to be treated by melting and 40% by incineration in 2007. (Table 1)

Melted slag produced from melting furnaces can be used as construction materials, such as admixture for backfilling soil used in open-cut construction work and admixture for cement, meaning that slag becomes commercially salable to private enterprises. This can save on expenses for landfill disposal of the incinerator ash, and allows the project to establish a sludge treatment system that is not affected by the constraints of landfill sites. Thus, it is proposed that all the generated sludge should be treated by melting, and all the generated slag be sold to the private sector.

Table 1. Shift in final sludge disposal (Transition in volume of incinerator ash & slag generated) (Units: tons)

Disposal practice	2003	2004	2005	2006	2007 (projected)
Landfill (incinerator ash)	24,879	15,356	15,097	14,693	10,100
Brick manufacturing (incinerator ash)	582	588	429	457	0
Construction material (slag)	1,854	6,507	5,825	6,087	9,400

ECONOMIC INFORMATION

Since the contract conditions are different for each sewage treatment plant, the average electricity charges for the whole of the sewage facilities in Osaka City are given below for 2006.

- The figure was 11.4 yen per kWh according to the records for 2006.
- Osaka City adopts an escalated tariff structure in sewage charges according to the consumption of city water, and the basic charge is 550 yen for up to 10 m3, and 61 yen per 1 m3 from 11 m3 to 20 m3.
- The price of diesel fuel was 6,250 yen per 100 liters.
- A strict calculation of what percentage the operation and maintenance costs accounts for of the overall sludge treatment costs is difficult, however it is estimated to be between 50 and 60% based on a rough evaluation.

DISTRIBUTION AND MARKETING OPTION

In the beginning, water-permeable bricks were manufactured from the incinerator ash. However, as the demand for bricks in public works for roads and parks has decreased, the market for permeable bricks has shrunk. Therefore, brick manufacturing has become uneconomical and it has now been suspended.

There are various ways of recycling slag as a construction material, and the total quantity of slag currently generated is sold to private construction companies. Slag is used as a partial substitute for fine aggregate (sand) in concrete products, as a blending material to improve the soil for backfilling, and as a partial substitute for sand in concrete where strength is not required.

USE ON AGRIGULTURAL LAND

Until around 1950, night soil collected from residences used to be taken to farmland on the outskirts of the cities. But night soil is no longer spread on farmland due to the widespread use of chemical fertilizers and the advances of urbanization. Currently, farmland use of night soil is no longer seen in Osaka City.

COASTAL RECLAMATION

Dewatered sludge is subjected to either combustion in incinerators or melting in furnaces. Incinerator ash generated by incineration is disposed of in two coastal reclamation sites. When the incinerator ash is dumped on the reclamation site, the result of a leachate test on the ash must meet the permits set by each reclamation site. Table 2 shows the leachate permits and the leachate test results for the incinerator ash from Osaka City.

Table 2. Permits at reclamation sites and leachate test results for incinerator ash from Osaka City

Toxic Parameters	Permits at Hokko Landfill Site	Permits at Izumi-otsu Landfill Site	Incinerator Ash Leachate Test Results FY 2007 (Maximum Values)	Units
Alkylmercuric compounds	Must not be detected	Must not be detected	ND	mg/L
Mercury or its compounds	0.005	0.005	ND	
Cadmium or its compounds	0.3	0.1	ND	
Lead or its compounds	0.3	0.3	ND	
Hexavalent chromium compounds	1.5	0.5	ND	
Arsenic or its compounds	0.3	0.3	0.22	
Specified organophosphorus	1	1	ND	
Cyanide	1	1	ND	
Polychlorinated biphenyl (PCB)	0.003	0.003	ND	
Trichloroethylene	0.3	0.3	ND	
Tetrachloroethylene	0.1	0.1	ND	
Selenium or its compounds	0.3	0.3	ND	
Dichloromethane	0.2	0.04	ND	
Carbon tetrachloride	0.02	0.02	ND	
1.2-Dichloroethane	0.04	0.04	ND	
1.1-Dichloroethylene	0.2	0.2	ND	
Cis-1,2-Dichloroethylene	0.4	0.4	ND	
1,1,1-Trichloroethane	3	3	ND	
1,1,2-Trichloroethane	0.06	0.06	ND	
1,3-Dichloropropene	0.02	0.02	ND	
Thiram	0.06	0.06	ND	
Simazine	0.03	0.03	ND	
Thiobencarb	0.2	0.2	ND	
Benzene	0.1	0.1	ND	
Dioxins	3	3	0.000017	ng-TEQ/g

ND: Not detected

INCINERATION OPTION

In Osaka City, incineration ash had been dumped at coastal reclamation sites after total sludge incineration. However, securing reclamation sites for a final disposal became difficult and it has been necessary to seek a recycling-oriented disposal method. Therefore, melting furnaces have been introduced that can melt the ash from dewatered sludge by burning at high temperature and produce slag having less volume than before. Moreover, the beneficial recycling of the melted slag as construction materials has led to a reduction in the final materials dumped at reclamation sites.

BENEFICIAL USES OF RESOURCES DERIVED FROM SLUDGE

At present in 2007, 27,000,000 m^3 of digestion gas is generated annually from six sewage treatment plants in the whole of Osaka City. Table 3 shows the rate of utilization of the digestion gas in 2007. Major application of the digestion gas in the beginning was for heating the digestion tank and as auxiliary fuel for the incinerator. Even at present, 80% of the digestion gas is still used for these purposes. As another option, power generation using a gas engine has been employed, and 13% of the digestion gas is currently used for power generation. The power generation system using digestion gas adopts a cogeneration system that recovers the waste heat generated through power generation, and this system has an excellent overall operation efficiency of over 70% and is worth being widely adopted in the future. As a next generation option, various practical beneficial uses of the digestion gas can be attempted, including use for fuel cells and air conditioners.

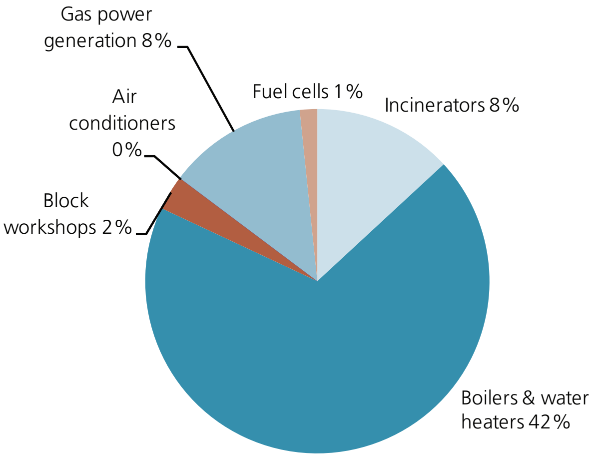
On the other hand, with the progress of sludge treatment centralization, the number of treatment plants that have incinerators is decreasing, and it is getting difficult to use the digestion gas on site as an auxiliary fuel for incinerators, resulting in 40% of the digestion gas becoming surplus gas in 2006. (Table 3, Fig. 4)

Table 3. Production and utilization of digestion gas generated in fiscal 2006

Application	Annual Consumption (Nm^3/Year)	Percentage of Total Volume of Gas Consumption	Percentage of Total Volume Generated
Incinerators	2,175,600	13%	8%
Boilers & water heaters	11,007,849	68%	42%
Brick manufacturing	566,320	3%	2%
Air conditioners	34,019	0%	0%
Gas power generation	2,147,430	13%	8%
Fuel cells	300,588	2%	1%
Total volume of gas consumption	16,231,806	100%	61%
Surplus gas	10,165,053	-	39%

In 2007, Osaka City started to operate a digestion gas power generator as one of the beneficial uses of the digestion gas, adopting the PFI scheme, which can make the most of the know-how and funds of private enterprises. It is planned that the digestion gas generated can supply up to 35% of the electric power used at the Tsumori Sewage Treatment Plant. The ratio of overall beneficial uses of digestion gas is expected to increase to 80% with this project. Digestion gas is a carbon-neutral energy source, greatly contributing to the prevention of global warming, and we are now considering introducing an additional effective system in order to further raise the ratio of beneficial uses of digestion gas.

Figure 4. Percentage of total volume generated in fiscal 2006



Slag

Until now, slag has been used in various construction materials. The following shows the general scope of applications for slag.

1. Aggregate for roads (admixture for asphalt)
2. Aggregate for concrete (crushed sand for concrete)
3. Secondary concrete products (interlocking blocks, etc.)
4. Banking material, backfilling material, covering material
5. Others (tiles, floor material, etc.)

Slag is a very stable material and it meets the requirements of the Soil Contamination Countermeasures Law. Even if slag is discharged into the environment, it will not cause any problems; therefore there are few impediments to the beneficial use of slag in that sense. The following table shows the legal requirements and the slag test results for Osaka City (2006).

Table 4. Environmental requirements in the Soil Contamination Countermeasures Law in Japan and the test results for slag from Osaka City (2006)

Parameters	Major Environmental Requirements in the Soil Contamination Countermeasures Law		Test Results for Slag from Osaka City	
	Leachate test (mg/L)	Content test* (mg/kg)	Leachate test (mg/L)	Content test* (mg/kg)
Cd	<0.01	<150	ND	ND
Pb	<0.01	<150	ND	50
Cr^{6+}	<0.05	<250	ND	ND
As	<0.01	<150	ND	ND
T-Hg	<0.0005	<15	ND	ND
Se	<0.01	<150	ND	ND
F	<0.8	<4,000	ND	42
B	<1.0	<4,000	ND	110
T-CN	ND	<50	ND	ND

Note: In this law, the quantity of substance leached by two hours of shaking with a 1 mol/L concentration of hydrochloric acid is considered as the content.

Japanese Industrial Standards (JIS) that stipulate the specifications to be met when melted slag is used as aggregate for concrete, aggregate for asphalt for roads and subbase course materials were established in 2006 for the purpose of promoting further utilization of melted slag.

These standards classify slag into coarse aggregate and fine aggregate by particle size, and stipulate the quality, test method and scope of use for each category. The standards for leaching and content of toxic substances are the same as those in the above-mentioned Soil Contamination Countermeasures Law. (Note; T-CN is not included in the JIS standards.) Table 5 shows the standards for the physical properties of aggregate for concrete.

Table 5. Standards for the physical properties of aggregate for concrete

Physical Properties	Melted Slag Coarse Aggregate	Melted Slag Fine Aggregate
Absolute dry density	2.5 g/cm^3 or more	2.5 g/cm^3 or more
Water absorption	3.0% or less	3.0% or less
Stability	12% or less	10% or less
Solid content	55% or more	53% or more
Content of fine grain	1.0% or less	7.0% or less

In Osaka City, production of melted slag has been increasing. Recycling as backfilling material in sewage works was the major option before 2003. In 2004, melted slag was sold as improvement material for soft soil, which would limit the choices for ground utilization after the landfill was completed because of its low strength. In 2005, Osaka City started selling melted slag to private business operators via public tender.

The slag generated in Osaka City is melted slag that is granulated by rapid quenching with water. When this granulated slag is evaluated in terms of indices such as solid content etc., it cannot be regarded as a substitute for sand as is in many cases. In order to meet the aforementioned JIS standards, additional processing is necessary, which would involve extra equipment costs and operation and maintenance costs. However there is little expectation of recovering those costs from the income from selling this compatible slag. On the other hand, when the slag is processed, the residue generated would need to be disposed of as waste, and the entire amount of slag would not be fully recycled. For these reasons, Osaka City is utilizing slag in limited applications where conformity to JIS standards is not required. For instance, slag is utilized as aggregate for concrete where strength is not crucial, such as in leveling concrete and slab concrete.

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Overview of sewerage system in Sapporo

The city of Sapporo has a total area of 1,121 km^2 (urban district: 249 km^2). With its center at 43°03' 34" N and 141°21' 29"E, the city extends about 42.3 km from east to west and about 45.4 km from south to north.

The climate of Sapporo is characterized by a comfortable summer and cold, snowy winter. The city has four distinct seasons and its annual average temperature is about 8.5°C.

Sapporo started large-scale construction of its sewerage system in 1926, and invested heavily in its construction in time for the Winter Olympics in 1972. In 1967 the Soseigawa Wastewater Treatment Plant, operating a conventional activated-sludge process, started as Sapporo's first large-scale wastewater treatment plant. Its sludge treatment processes consisted of chemical conditioning of concentrated sludge with ferric chloride and lime, followed by dehydration. The method has continued to be the basic sludge treatment process in Sapporo's sludge treatment plants.

As of 2006, ten wastewater treatment plants have been in operation with a total capacity of about 1,200,000 m^3/day. The proportion of the population of Sapporo served by sewers now stands at 99.6% (see Table 1).

To reduce the amount of sludge disposal, the Teine Sewage Sludge Incineration Center was constructed in 1983 and the Atsubetsu Sewage Sludge Compost Plant was constructed in 1984 as part of the centralized sludge treatment project.

Since then, Sapporo has promoted the construction of centralized sludge dehydration and incineration plants to raise the efficiency of sludge treatment operations. The West Sludge Treatment Center, which covers the western part of Sapporo, started to operate in 2000, and the East Sludge Treatment Center, which covers the eastern part of Sapporo, started to operate in 2007.

Table 1. Overview of Sapporo's sewerage system in 2006

Total population (thousands)	1,888
Urbanized area (ha)	24,930
Length of sewer pipe (km)	8,084
Sewer-served area (ha)	24,493
Sewer-served population (thousands)	1,880
Population with flush toilet (thousands)	1,874
Ratio of sewer-served population (%)	99.6

TREATMENT AND UTILIZATION OF SEWAGE SLUDGE

Sludge treatment

Two methods of treating sludge are used in Sapporo. One is mixing of primary and excess sludge, gravity thickening, chemical conditioning with $FeCl_3$ and $Ca(OH)_2$ and dewatering by filter presses at each wastewater treatment plant. The other is centralized sludge treatment, in which, after gravity thickening at each wastewater treatment plant, thickened sludge is sent to a Sludge Treatment Center in sludge pipes by pressure and dewatered by a centrifugal dehydrator with polymer.

As shown in Table 2, in 2006 Sapporo's sewerage system produced 547 tons of dewatered sludge from 4,780 m^3 of concentrated sludge, of which the concentration was 3.4% DS. Of the dewatered sludge, 91% is incinerated, 8% is used as a material for compost and the rest is mixed with cement as a raw material.

Table 2. State of sludge treatment (daily average in 2006)

Total amount of wastewater treatment (m^3/day)	Sludge generated in thickening tank (m^3/day)		Thickened sludge (m^3/day)	Treated sludge as dry solid (m^3/day)	Amount of dewatered sludge (t/day)	
	Primary sludge	Excess sludge			Pressure dehydration	Centrifugal dehydration
1,056,000	29,293	17,267	4,780	162	199	348

Stoker-type furnaces are employed at the West Sludge Treatment Center. The heat generated by incineration is used for drying the dewatered sludge. The water content of dewatered sludge is about 45%, therefore dewatered sludge is almost entirely incinerated on its own and requires little auxiliary fuel.

Incineration ash from the West Sludge Treatment Center is characterized by a porous consistency with coarse grains of sand and gravel. The ash is uncompacted but does not scatter and is easy to handle. Various studies and tests are being conducted on using the incineration ash from the stoker furnaces as material for construction works.

On the other hand, the fluidized bed furnace has been employed at the East Sludge Treatment Center since 2007. The ash is powdery, so it is sent to a cement plant to be used as a material for producing cement.

Table 3 gives outline information on sludge treatment plants. In fiscal year 2006, the West Sludge Treatment Center produced 23,648 tons of incineration ash. Recently, the ash has not been disposed of in landfills because it is difficult to find suitable sites and landfills are very expensive to construct.

Sludge composting in Sapporo

Composting of benchmark sludge

This is a possible alternative for using benchmark sludge. It can be transformed into compost and used, but first it is necessary to reduce the heavy-metal content (especially mercury). After the concentration of heavy metals in sewage sludge has been reduced to levels where the sludge can be used for green areas and agricultural land, the sludge is dehydrated by chemical conditioning and transported to the Atsubetsu Compost Plant. Transported sludge and other types of dewatered sludge are transformed into compost at the plant.

Sludge composting

Utilization of sewage sludge for green areas and agricultural land in Sapporo started with direct utilization of dewatered cake suitable for combining dewatered sludge compost and organic matter. At that time, the sewerage service area was expanding and the amount of dewatered sludge was rapidly increasing. Dewatered sludge was difficult to transport and had limited uses. Another major problem was reducing the high viscosity and foul odor of the dewatered sludge itself.

In 1976, comprehensive research on future treatment methods and uses of sludge was conducted, paving the way for 'incineration treatment of sludge and promotion of incineration ash utilization' and 'transforming sludge into compost and promotion of its utilization for green area and agricultural land'.

In 1982, construction of the Atsubetsu Sewage Sludge Compost Plant (primary fermentation tank, horizontal paddle type, secondary fermentation tank, windrow type) began and in 1984 the plant started operation, with a daily capacity of 50 tons as dewatered sludge. After the plant entered operation, the direct application of dewatered sludge to green land and agricultural land gradually decreased, and since 1989 sludge compost has replaced dewatering sludge.

The Atsubetsu Sewage Sludge Compost Plant now has an expanded capacity of 75 tons per day. As well as a powder compost producing process, the plant also has a granular compost producing facility (water-added-roller type, 10 tons per day) to meet the needs of compost users. Granular compost is so popular that all products have now been changed to the granular type.

Production of compost

It is necessary to have a strict screening process to obtain proper dewatered sludge as materials for compost, because users insist on safety and a stable supply system of compost products.

With regard to the safety of compost, dewatered sludge generated from the Atsubetsu Wastewater Treatment Plant is primarily used as a material for compost because the plant has only a few factories that discharge effluent containing heavy metals in its service area. Furthermore, the Sapporo City authority takes precautions to minimize the inflow of heavy metals into the plants, such as city officials offering advice to the factories, and encouraging them to install equipment to regularly monitor and eliminate heavy metals.

With regard to materials for compost, only sewage sludge is now transformed into compost without additives, owing to production scale, conditions of location and other factors.

Table 4 shows heavy metals, compost constituents and other items and compost products for the Atsubetsu Sewage Sludge Compost Plant.

Utilization of compost

In 2006 about 3,800 tons of compost were used within a radius of about 100 km (centered on Sapporo). Half was used for agricultural land and the rest for green areas.

Utilization of compost for crops is 85% for wheat, beans and vegetables, and 15% for grass. In addition, compost is used for fruit trees.

Legal regulation of sludge utilization for agricultural lands

With regard to utilization of sewage sludge for agricultural lands, activated sludge fertilizer and sludge fertilizer were categorized under the Fertilizer Control Law, which was enacted in 1950, so the distribution and utilization of sewage sludge have quite a long history. Nowadays, the environmental aspects of resources have attracted attention and the legal situation for using sewage sludge on agricultural lands has gradually been improved.

1. Fertilizer Control Law (1950)

   Fertilizer made of sewage sludge is classified as a special fertilizer under the Fertilizer Control Law. Content control standards are applied to arsenic, cadmium, mercury, nickel, chromium and lead (Table 5). Furthermore, for fertilizer produced for sale or transfer, producers of special fertilizers must submit reports on the name of producers, production amounts and production procedures to public authorities. There is also a limit of 120 mg/kg of zinc in sludge-amended soils.

2. Waste Disposal and Public Cleaning Law (1973)

   Sludge that can be used for green areas and agricultural land must meet the standards of the Prime Minister's Office Ordinance for Establishing Evaluation Standards Regarding Industrial Wastes, Including Metals (Table 6). The Ordinance was revised in 1994, when 13 substances were added to it.

Future plans for sludge disposal

Operation and maintenance costs (except capital cost) to produce compost are estimated to be approximately ¥500 million per year.

It costs about ¥30,000 to produce compost from 1 ton of dewatered sludge, whereas the cost of incineration is about ¥7,000-9,000, so incineration is cheaper than composting. Other problems include the following:

1. The facilities and equipment of the Atsubetsu Compost Plant are so superannuated that repair costs are very high.
2. As residential areas have spread, houses will be built near the Compost Plant, so odors from the plant must be controlled more strictly.
3. Recently some private companies have started to build compost plants, which are cheaper to construct, operate and maintain than our plant. If we wish to produce compost, we must do so more cheaply.
4. The sale volume of compost has been decreasing, causing costs to rise.

For these reasons Sapporo City has decided to stop producing compost after a few years. Sludge disposal of Sapporo will be done almost entirely by incineration.

Table 3. Sludge treatment plants

Treatment process	Atsubetsu Treatment Plant Chemical conditioning and filter press	West Sludge Treatment Center Polymer and centrifugal dehydrator
Generated sludge to thickener		
Primary sludge (m3/day)	3,524	–
Excess sludge (m3/day)	2,318	–
Thickened sludge:		
Amount (m3/day)	884	2,416
Ratio of dry solid (%)	3.1	3.6
Ratio of organic matter in dry solid (%)	84.5	74.4
Ratio of chemical dose:		
FeCl3 (%)	7.6	–
Ca(OH)2 (%)	29.5	–
Polymer (%)	–	0.27
Amount of dewatered sludge:		
Amount (m3/day)	90	343
Ratio of dry solid (%)	35.9	24.1
Ratio of organic matter in dry solid (%)	66.9	73.0
Incineration ash (t/day)	–	65

Table 4. Compost constituents and heavy metals in compost

Compost constituents:	
pH	8.2
Water content (%)	11
Organic matter in dry solid (%)	39
CaO (%)	21
T-N (%)	2.1
P_2O_5 (%)	3.1
K_2O (%)	0.1
MgO (%)	0.5
Heavy metals (mg/kg dry wt):	
As	7
Cd	≤1
Hg	0.19
Ni	35
Cr	29
Pb	10
Cu	140
Zn	300

Table 5. Control standards (mg/kg DS) for sewage in Fertilizer Control Law

Item	Standard
As	≤ 50
Cd	≤ 5
Hg	≤ 2
Ni	≤300
Cr	≤500
Pb	≤100

Table 6. Prime Minister's Office ordinance for establishing evaluation standards regarding industrial waste, including metals (1995)

Toxic substance	Concentration standard (max. allowable mg/l in extracted solution)
Alkyl mercury compounds	ND
Mercury and its compounds	0.005
Cadmium and its compounds	0.3
Lead and its compounds	0.3
Organic phosphorous compounds	1
Hexavalent chromium	1.5
Arsenic and its compounds	0.3
Cyanide compounds	1
PCB	0.003
Trichloroethylene	0.3
Tetrachloroethylene	0.1
Dichloromethane	0.2
Carbon tetrachloride	0.02
1,2- Dichloromethane	0.04
1,1- Dichloroethylene	0.2
cis-1.2-Dichloroethylene	0.4
1,1,1- Trichloroethane	3
1,1,2- Trichloroethane	0.06
1,3- Dichloropropene	0.02
Thiuram	0.06
Simazine	0.03
Thiobencarb	0.2
Benzene	0.1
Selenium and its compounds	0.3
Dioxin	3 (ng/g)

ND: not detectable

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Outline of Suzu City

BACKGROUND

Present state of Suzu City

Suzu City is located at the tip of the Noto Peninsula, which juts out into the central area of the Sea of Japan and where mountains or forests cover about 80% of the area. Almost all of the coastline on the three sides of the city is designated a state park because of its rich nature and scenic beauty.

Coastal fishery and the tourist industry are key industries for the local government. The city covers an area of 247 km^2 and its population was 18,759 in March 2007. The peninsula has been designated as an under-populated area that is to be promoted.

Present state of sewage works

Suzu City has two wastewater treatment districts: the Suzu district and the Horyu district. By the end of FY 2006, the service area amounted to 271 ha, and the proportion of the population served by sewers was 31%. The Suzu district has been partially treating its wastewater since 1991, and the Horyu district since 2004. The city employs the separate sewer system and oxidation ditch method, with treatment facility capacities of 3,600 m^3 per day and 900 m^3 per day, respectively.

In other areas that have no sewerage systems, wastewater treatment by the agricultural wastewater system (Wakayama dai-ichi district, 86 ha) and purification tanks has been introduced, and so the proportion of the population covered by the entire system is now 49%.

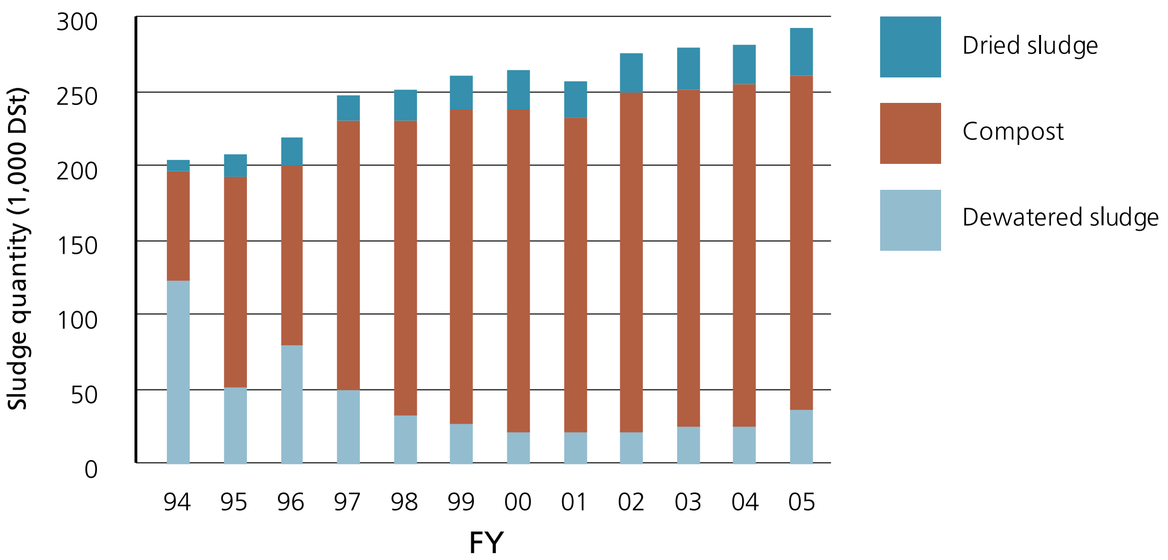
The quantity of generated sewage sludge (dewatered sludge, water ratio 83%) was 329 t per year (FY 2006). Of this, 23 t of dewatered sludge was disposed of in landfills after incineration, 147 t was used for soil improvement, and the remaining sewage sludge (159 t) was used as fertilizer after drying. Since FY 2007, mixed sludge of sewage sludge, other kinds of wastewater sludge (such as purification tank sludge) and garbage have been treated by mixed methane fermentation, and the residue after treatment (digested sludge) has been dried and used for agriculture and forestry.

UTILIZATION OF SEWAGE SLUDGE FOR AGRICULTURE AND FORESTRY

Present state of agricultural and forestry use

Of the total sewage sludge generated in Japan, 14% is used for agriculture and forestry and the amount has been increasing slightly year by year (Figure 1). The proportion of compost is as large as 73%, and that of dewatered sludge and dried sludge are 12% and 11%, respectively. Composting and use for agriculture and forestry have long been practical methods for recycling sludge and may help to create recycling-based societies in rural areas.

Figure 1. Transition of sewage sludge quantity for agricultural and forestry use in Japan



Standards of quality management

The Fertilizer Regulation Act was amended in 2000, introducing quality management for fertilizer made of sludge and regulating the maximum amounts of six hazardous compounds. In addition to arsenic, cadmium and mercury, the amendment introduced new criteria for nickel, chromium and lead. Table 1 shows measurements for dried sludge, which is used for producing fertilizer in Suzu City. The dried sludge satisfies the criteria for fertilizer.

As for fertilized soil, the maximum amount of zinc (120 mg per 1 kg dried soil) is regulated as a management standard for protecting agricultural soil. Furthermore, the Japanese Agricultural Association determines the amount of copper (under 600 mg per 1 kg dried fertilizer made of sludge) and zinc (under 1,800 mg), and requires that the concentration should be indicated if the contents of copper and zinc exceed 300 mg and 900 mg, respectively. The concentration of copper and zinc per 1 kg dried sludge in Suzu City are 300 mg and 720 mg, respectively.

Table 1. Measurements of dried sludge [mg/kg]

		Measurement of dried sludge	Criteria for fertilizer
Arsenic	As	8,2	50
Cadmium	Cd	2,2	5
Mercury	Hg	1,1	2
Nickel	Ni	32,3	300
Chromium	Cr	19,5	500
Lead	Pb	5,2	100

OUTLINE OF PROJECT FOR BIOMASS UTILIZATION

Suzu: Plan for practical use of biomass energy

Suzu City has introduced a facility at the Municipal Sewage Purification Center that accepts and uses night soil, sludge from on-site sewage treatment as well as from public and rural sewerages, and industrial waste. This pioneering project for biomass utilization is the first to be awarded by the Ministry of Land, Infrastructure and Transport (MLIT). It is also the first cross-boundary biomass project co-supported by MLIT and the Ministry of the Environment. Construction of the facility was completed in March 2007, and full-scale operation of the fermentation facility was started in August 2007 after 5 months of trials.

The sludge mixture is treated by methane fermentation in a fermentation tank to generate biogas, which is used as an energy source for the boiler. Steam generated by the boiler is used to heat the fermentation tank and to dry the fermentation residue (sludge). Dried sludge is recycled as fertilizer in the local area, thus helping to build a recycling-based society with zero discharge.

Outline of the methane fermentation

Planned quantity of biomass treatment

The planned quantity of biomass treatment is 32.9 t (daily average value) and 51.5 t (daily maximum value), which are accepted at the methane fermentation facility (Table 2). The garbage would be industrial waste, which includes mixed garbage from protective care facilities, bony parts from fishing associations, and waste from marine-product factories and so on.

Table 2 Planned quantity of biomass treatment [tons/day]

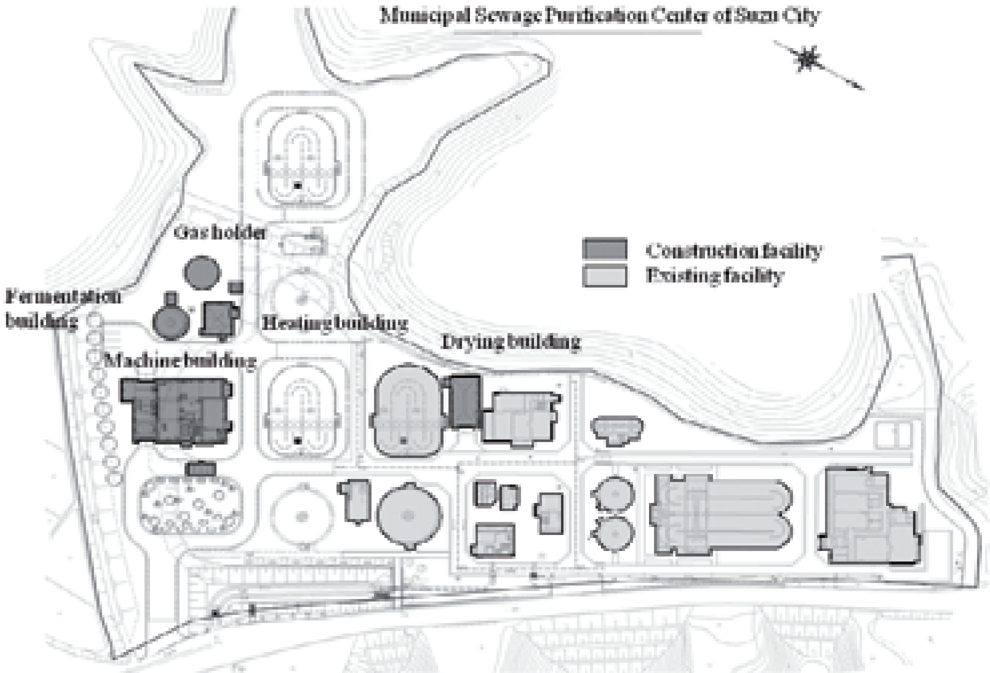
Biomass	Average value	Maximum value
Sewage sludge	15,3	22,5
Agricultural sewage sludge	0,5	0,7
Purification tank sludge	8,1	14,6
Night soil	7,6	11,3
Garbage	1,4	2,4
Total	32,9	51,5

Composition of the methane fermentation facility

The composition of the methane fermentation facility is as follows (Figure 2): 1) machine building to receive and pre-treat biomass except sewage sludge; 2) fermentation building for methane fermentation; 3) gas holder for temporary biogas storage; 4) heating building to produce hot water for heating the fermentation building by using biogas; 5) drying building to dry dewatered sludge; 6) sludge treatment building to dewater digested sludge.

The sludge treatment building is an existing facility, but it was partially improved with the construction of equipment for transporting dewatered sludge to the next drying building.

Figure 2. Municipal sewage purification center of Suzu City



Outline of equipment

The methane fermentation facility consists of the following equipment (Figure 3): 1) receiving and pre-treatment equipment, which includes a garbage crushing and separation machine, solubilization tank, thickening machine and so on; 2) methane fermentation equipment, which includes a mixing tank and methane fermentation tank (Photo 1); 3) biogas utilization equipment, which includes a gas holder, dried de-sulfurization equipment, boiler and so on; 4) dewatering and dried equipment, which includes a sludge dewatering machine and indirect steam heating dried machine; and 5) deodorization equipment, which includes a biological deodorization apparatus and activated carbon adsorption tower.

Figure 3. Schematic diagram of biomass methane fermentation facility

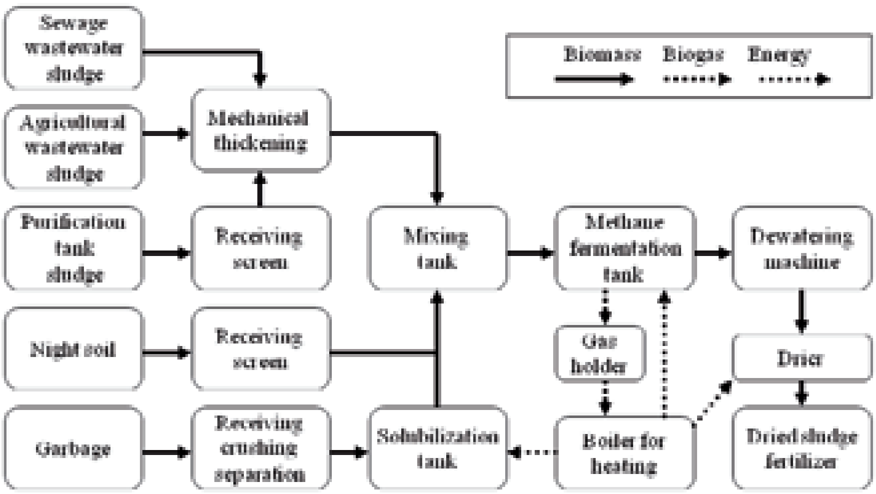


Photo 1. Methane fermentation tank

Photo courtesy of the authors.

EFFECT OF FACILITY CONSTRUCTION

The feasibility study showed that construction of the methane fermentation facility could both reduce cost and improve the environment: 1) for a new treatment facility for night soil (sludge recycling center), the construction cost would be 56.5 million yen per ton for the scale of Suzu City. In contrast, as a result of intensive treatment of night soil, the fermentation facility would greatly reduce the construction cost to 24.7 million yen per ton because of the scale merit of intensive biomass treatment; 2) the cost of sludge disposal would be zero, because the treatment residue (digested sludge) is dried and used as fertilizer; 3) CO_2 gas emission generated from facility operation would be reduced by 290 kg per day by the new treatment facility in comparison with treating each biomass individually.

Suzu City is assessing the performance of actual equipment from FY 2007 to FY 2008, because the effects of facility construction assume maximum performance.

CONCLUSION

To attain the goals of the Kyoto Protocol and Biomass Nippon Strategy, reuse of unused biomass (in particular, sludge-based biomass for its mass of volume) as an energy source is essential in order to create a recycling-based society.

By launching the biomass project, Suzu City is trying comprehensively to resolve the following issues: 1) maintaining sewage sludge disposal sites; 2) the rising cost of disposing of sewage sludge; 3) the need to construct a new night soil treatment facility; and 4) the treatment of industrial waste, mainly from marine-product processing, which is a major industry in Suzu City, while simultaneously helping to form a good local recycling-based society and mitigate global warming effects.

Outline of sewerage system in Tokyo

PLANNING FOR TOKYO'S SEWERAGE SYSTEM

The Bureau of Sewerage, Tokyo Metropolitan Government, is responsible for the construction and management of the sewerage system for the 23 wards of Tokyo, the service area of which is 578.39 km^2. It is also in charge of the construction and management of trunk sewers and water reclamation centers for the Tama area, with a service area of 489.39 km^2. Construction of the sewerage system in Tokyo started in earnest in 1908, following the release of the Tokyo City Sewerage Plan, which served as the foundation for the present plan. The projected sewered population was 3,000,000 and the projected service area was 56.7 km^2. In 1922 the first wastewater treatment in Japan started operation at the Mikawashima wastewater treatment plant.

The sewered population rate reached 100% at the end of fiscal year 1994 in the ward area. The total population of Tokyo was 12,737,099 (8,651,269 in the ward area and 4,056,982 in the Tama area), the number served by sewers was 12,568,420 (8,642,220 in the ward area and 3,926,200 in the Tama area) and the total length of sewer pipes was 15,892,446 m (15,675,672 m in the ward area and 216,774 m in the Tama area) at the end of fiscal year 2006.

TRANSITION OF SLUDGE TREATMENT METHOD AND REUSE IN TOKYO

Change in sludge treatment and reuse

The sludge generated in Tokyo used to be disposed of in the sea until the mid 1940s. A portion was dried and used as manure for farmland until the 1960s. Thereafter, the situation of sludge treatment and disposal changed greatly due to the progress in sewerage development, increase in the amount of sludge, advance in urbanization and so on. Because of problems finding secure disposal sites and dealing with odors, it was hard to use dried sludge as manure for farmland. At present, sludge is reduced in volume and then stabilized for disposal in landfill. The transition in the treatment and disposal of sludge is shown in Table 2.

The present status of sludge treatment

At present, the sludge generated from 13 water reclamation centers in the ward area is treated in five water reclamation centers and two sludge plants. The sludge generated from the water reclamation centers that have no sludge treatment facilities is pumped to water reclamation centers that have sludge treatment facilities or to sludge treatment plants. The sludge treatment process in Tokyo is mainly composed of thickening (digestion), dewatering and incineration, and this reduces the sludge volume to one-hundredth. This is the system in which the benchmark sludge could be accommodated.

The types of dewatering machine and the amount of sludge treated by each type are: centrifugal, 79%; belt-press, 14%; and vacuum, 7%. The types of incinerator are: fluidized-bed combustor, 94%, and multiple-hearth furnace, 6%. The capacities of incinerators and standards of air pollution in the ward area are shown in Table 3. Great care is taken with environmental protection measures during sludge incineration in Tokyo.

The present status of sludge reuse

In fiscal year 2006, the actual daily average wastewater flow in the ward area of Tokyo was approximately 4,800,000 m^3 and treatment was carried out at 13 water reclamation centers. The average raw sludge amounted to 180,000 m^3 per day, and was treated in five water reclamation centers and two sludge plants. The daily average dewatered sludge was approximately 2,700 tons and 100% of it was incinerated to extend the lifespan of landfills. A total of 120 tons of sludge ash was generated daily, and 77 tons (64%) of it was recycled as construction materials. This would be the preferred option for the benchmark sludge. The remaining sludge ash was mixed with special cement for stabilization, and was disposed of in landfill. The landfill amount was 43 tons (36%) of sludge ash per day. The situation is shown in Figure 2.

In fiscal year 2006, 56% of sludge ash was used as a raw material for cement; 33% was used as a raw material for lightweight aggregate; 7% was converted to a particular size conditioned ash (Super ash) for construction material; 4% was used to produce lightweight aggregate made of 100% sludge ash (Sludgelight). Figure 3 shows the quantity of each type.

Since fiscal year 2007, carbonized material has been produced from dewatered sludge and the product is used at a thermal power station mixed with coal. This project is the first such attempt in Japan. The carbonized process is shown in Figure 4. This project promotes the utilization of sludge (about 10% of the annual amount of sludge generated is used for carbonization) and reduces GHG by 37,000 tons CO_2 equivalent compared with the usual sludge incineration.

In the Tama area, a sludge gasification furnace that generates combustible gas from sludge by pyrolyzing the sludge under low oxygen concentration will be built. This process also reduces GHG.

Disposal by sanitary landfill

In Tokyo, all of the sludge is incinerated and the ash is mixed with special cement to be disposed of in coastal landfills. The sludge-cement mixture is examined by leachate tests to assure its environmental safety. The test is conducted according to the 'Ministerial Ordinance for Establishing Evaluation Standards regarding Industrial Wastes, including Metals'. The results of the leachate test are shown in Table 4.

ECONOMIC INFORMATION

The operation and maintenance costs of water reclamation center in fiscal year 2006 in Tokyo are shown in Table 5; the service charges are shown in Table 6.

- Cost of 100 liters of diesel fuel: about ¥13,500
- Cost of 1 kWh of electricity: ¥16.05.

Table 1. General facts and figures on planning for Tokyo's sewerage system (for the ward area) (City plan as of 6 April 2007)

	Projected sewered population	Drainage area (ha)	Pumping stations (number)	Water reclamation centers (number)	Water reclamation centers Design capacity (m^3/day)
Total	9,093,000	57,839	86	16	8,290,000
Shibaura	684,000	6,440	13	1	1,370,000
Mikawashima	811,000	3,936	8	3	860,000
Sunamachi	960,000	6,153	30	2	1,070,000
Odai	326,000	1,687	5	2	350,000
Ochiai	781,000	3,506	-	2	500,000
Morigasaki	2,109,000	14,675	14	1	1,540,000
Kosuge	264,000	1,633	3	1	260,000
Kasai	757,000	4,893	8	1	630,000
Shingashi	1,658,000	10,474	1	2	1,120,000
Nakagawa	743,000	4,442	4	1	590,000

Table 2. Changes in sludge treatment and disposal

Years	Treatment process				Disposal method
Up to 1960	Gravity thickening		Sludge drying beds		Disposal in the sea/ocean, land application
1960s	Gravity thickening	Digestion	Mechanical dewatering		Landfill
1970s	Gravity thickening	Digestion	Mechanical dewatering	Incineration	Landfill
1980s	Gravity and mechanical thickening	Digestion	Mechanical dewatering	Incineration	Landfill and recycling as resources

Table 3. Incinerator capacity, standards for air pollution and measured values of exhaust gases, fiscal year 2006

Treatment plant	Facilities' capacity (t/day)	SOx (m^3N/h)		SOx (m^3N/d)		Smoke and dust (g/m^3N)		Hydrogen chloride (mg/m^3N)		NOx (ppm)		NOx (m^3N/h)	
		STD	meas	STD	meas	STD	meas	STD	meas	STD	meas	STD	meas
Miyagi	200*3	2.9	0.011	81	0.3	0.08	0.001	700	2.5	250	11	16	0.3
Tobu sludge plant	300*1		0.035			0.08	0.001		1.5		8		
	300*1	26	0.083	225	5.9	0.08	0.001	700	1.5	250	7	21	0.7
	300*1		0.13			0.04	0.001		1.9		5		
Kasai	150*1		0.005			0.08	0.001		1.8		4		
	250*1	12	0.18	492	6.0	0.08	0.001	700	3.4	250	3	24	0.6
	300*1		0.042			0.08	0.001		2.8		7		
	300*1		0.022			0.04	0.001		2.7		8		
Shingashi	200*1	1.05	0.18			0.04	0.004		3.1		7		
	250*1	1.07	0.046	234	5.7	0.08	0.002	700	0.3	250	5	17	0.4
	250*1	0.73	0.016			0.08	0.003		0.7		5		
Nanbu sludge plant	300*1	1.1	0.010			0.08	0.003		1.5		60		
	300*1	1.1	0.12			0.08	0.003		2.0		84		
	300*1	1.1	0.004			0.08	0.001		2.0		10		
	300*1	1.1	0.035	758	9.0	0.08	0.001	700	2.0	250	8	52	23
	300*1	0.79	0.048			0.04	0.001		2.0		9		
	300*1	0.79	0.083			0.04	0.001		4.0		8		
	300*1	0.98	0.079			0.04	0.001		2.0		2		

STD: Standard
meas: Measured

Table 4. Standards for leachate and measured values of incinerated ash, fiscal year 2006

Item	Standard	Measured
Alkyl mercury compounds	Not detected	Not detected
Mercury and its compounds	0.005	Less than 0.0005
Cadmium and its compounds	0.3	Less than 0.01
Lead and its compounds	0.3	Less than 0.01
Organic phosphorous compounds	1	Less than 0.1
Hexavalent chromium	1.5	0.05
Arsenic and its compounds	0.3	Less than 0.01
Cyanide compounds	1	Less than 0.1
PCB	0.003	Less than 0.0005
Selenium and its compounds	0.3	Less than 0.01
Trichloroethylene	0.3	Less than 0.01
Tetrachloroethylene	0.1	Less than 0.01
Dichloromethane	0.2	Less than 0.02
Carbon tetrachloride	0.02	Less than 0.002
1,2-Dichloroethane	0.04	Less than 0.004
1,1-Dichloroethylene	0.2	Less than 0.02
cis-1,2-Dichloroethylene	0.4	Less than 0.04
1,1,1-Trichloroethane	3	Less than 0.3
1,1,2-Trichloroethane	0.06	Less than 0.006
1,3-Dichloropropene	0.02	Less than 0.002
Benzene	0.1	Less than 0.01
Thiuram	0.06	Less than 0.006
Simazine	0.03	Less than 0.003
Thiobencarb	0.2	Less than 0.02

Table 5. Operation and maintenance costs, fiscal year 2006

Treatment	Percentage	
Wastewater treatment		**63.8**
Sludge treatment		
Thickening/dewatering	16.6	
Incineration	16.7	
Resource for other material	1.7	
Mixing	0.7	
Landfill	0.5	
Total		36.2
Total		100

Table 6. Sewer service charge (per month)

Volume (m^3)	Monthly charge (¥)
Up to 8	560
9-20	+110/m^3
21-30	+140/m^3
31-50	+170/m^3
51-100	+200/m^3
101-200	+230/m^3
201-500	+270/m^3
501-1,000	+310/m^3
Over 1,001	+345/m^3

The charge is calculated by multiplying the figures in the above table by 1.05 (current consumption tax rate).

(*) The sewered population exceeds 99.5% and is considered equal to 100%.

Figure 1. Increase in sewered population

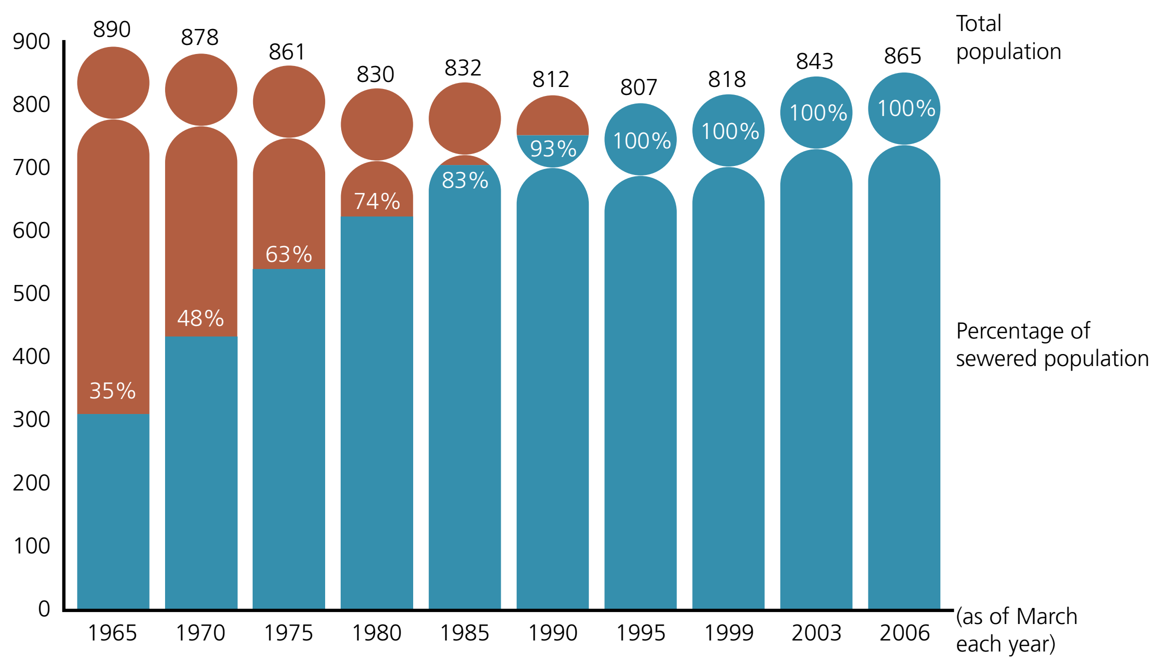


Figure 2. Sludge treatment and disposal in the ward area, fiscal year 2006 (annual)

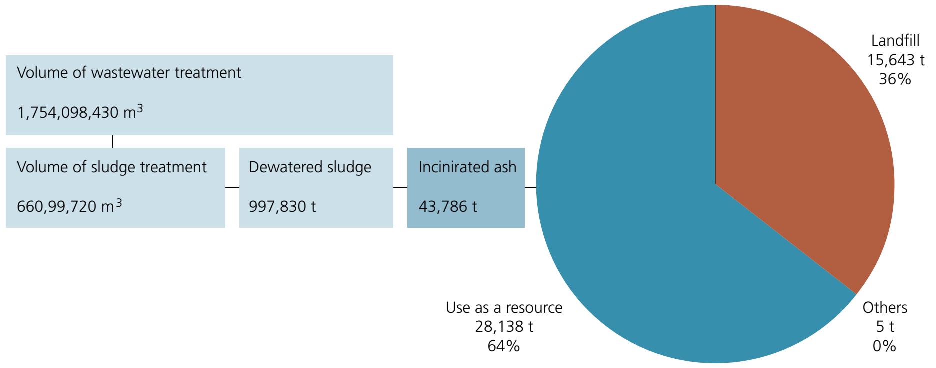


Figure 3. Sludge products as resources in the ward area, fiscal year 2006 (annual)

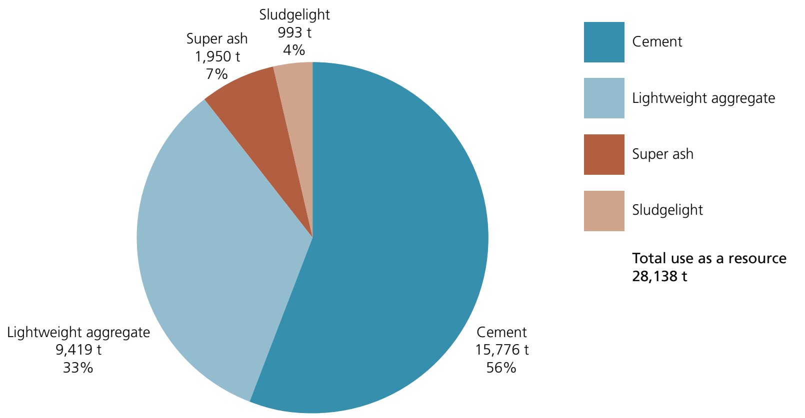
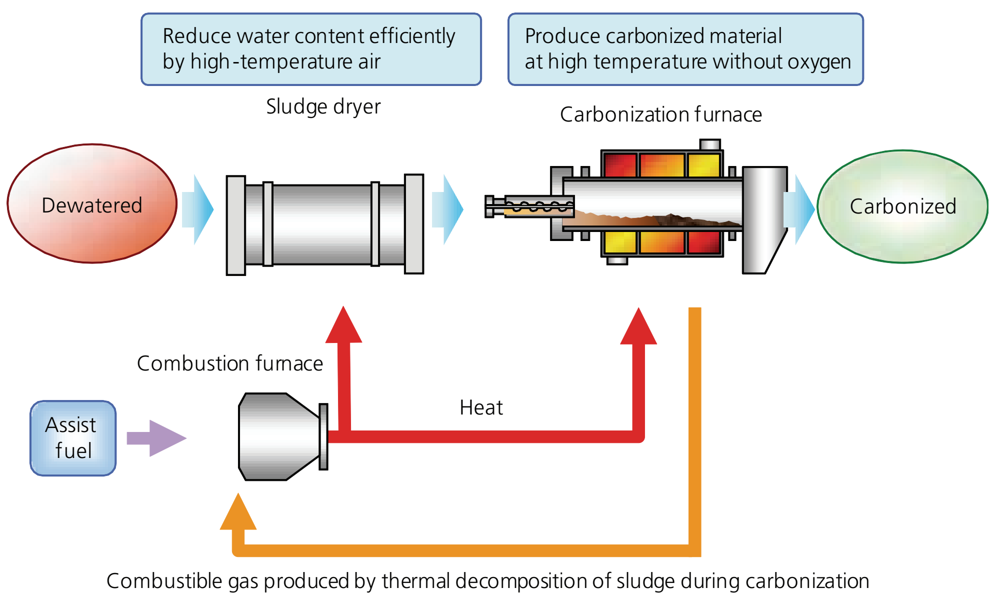


Figure 4. Schematic diagram of carbonization process



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Outline of sewage works in Yokohama

The sewer system in Japan was started as a sanitary measure following a major cholera outbreak in the 1870s. Since Yokohama City was an international trade port, construction of sewerage facilities began there, in the foreign settlement district, much earlier than in other cities in Japan.

Systematic construction of Yokohama's sewerage facilities began in 1950, starting from the primary period of sewerage works by acquisition of project approval in Ushioda, Heian and Ichiba in Tsurumi-ku.

Thereafter, the construction zone was extended in accordance with several five-year programs starting in 1963, and during this period, project approval under the Sewerage Law was obtained in almost all areas within the city by 1969. At the end of FY 2005, construction zones under approval covered 40,023 ha of the total city area of 43,498 ha.

From FY 2002, construction proceeded based on the city's "Mid-Term Policy Plan", at a cost of 4.86 billion yen by FY 2005. As a result, the area covered by treatment districts totaled 30,709 ha and the percentage of sewered population among the total population of the city had reached 99.7%.

Under Yokohama's sewerage plan, the entire city was divided into nine treatment districts according to the terrain. One or two wastewater treatment plants were established at each district, and by 1989, 11 wastewater treatment plants (WTPs) and 2 sludge treatment and recycling centers had begun operation. Thus, the number of facilities increased along with the progress of sewerage construction.

Table 1 outlines Yokohama's wastewater treatment plants, pumping stations and sludge treatment centers.

Further efforts will be made in the future to maintain and create a clean water environment through resolution for unsewered areas, control of combined sewer systems, and promotion of advanced wastewater treatment, as well as to create a disaster-resistant and safe town through emphatic maintenance measures against inundation. Furthermore, a recyclable society will be the target, through the effective use of sewerage resources and assets and the renewal of facilities, taking into consideration the promotion of labor and energy savings.

Sewerage construction incurs a huge amount of expenses. The necessary funds are derived from national subsidies, Sewage Works Construction Bonds and city expenditures. Finances related to the maintenance fees for constructed sewerage facilities consist of sewage service charges and city expenses (general account transferred), under the payment principle that expenses for rainwater treatment are covered by the city while those for drainage treatment are from sewage service charges.

In recent years, although the expenses for improving construction have been reduced, the principal redemption for the Sewage Works Construction Bonds issued earlier is increasing.

Table 1. Details of Yokohama's facilities

Wastewater treatment plant	Month and year of start-up	Treatment process	Capacity (m^3/day)	Sludge treatment process	Number of pumping stations
Hokubu I	July 1968	Conventional activated sludge process	140,000	Gravity thickening –> the Hokubu Center	6
		Advanced wastewater treatment (A_2O)	23,200		
Hokubu II	Aug. 1984	Conventional activated sludge process	116,500	Gravity thickening –> the Hokubu Center	3
Kanagawa	Mar. 1978	Conventional activated sludge process	299,400	Gravity thickening –> the Hokubu Center	4
		Advanced wastewater treatment (A_2O)	92,140		
Chubu	Apr. 1962	Conventional activated sludge process	96,300	Gravity thickening –> the Nanbu Center	1
Nanbu	July. 1965	Conventional activated sludge process	182,400	Gravity thickening –> the Nanbu Center	4
Kanazawa	Oct. 1979	Conventional activated sludge process	286,100	Gravity thickening –> the Nanbu Center	2
		Advanced wastewater treatment (A_2O)	44,320		
Kohoku	Dec. 1972	Conventional activated sludge process	211,800	Gravity thickening –> the Hokubu Center	4
		Advanced wastewater treatment (A_2O, AOAO)	82,620		
Tsuduki	May. 1977	Conventional activated sludge process	144,350	Gravity thickening –> the Hokubu Center	0
		Advanced wastewater treatment (AOAO)	82,800		
Seibu	Mar. 1983	Conventional activated sludge process	95,400	Gravity thickening –> the Nanbu Center	0
Sakae I	Dec. 1984	Conventional activated sludge process	62,000	Gravity thickening –> the Nanbu Center	1
		Advanced wastewater treatment (AO)	23,400		
Sakae II	Oct. 1972	Conventional activated sludge process	177,500	Gravity thickening –> the Nanbu Center	1
Total			2,208,630		26

Sludge Treatment and Recycling Center	Month and year of start-up	Treatment process	Capacity (m^3/day)
Hokubu	Sep. 1987	Mechanical thickening –> anaerobic digestion –> dewatering –> incineration –> recycle	12,500
Nanbu	Nov. 1989	Mechanical thickening –> anaerobic digestion –> dewatering –> incineration –> recycle	14,700

CURRENT STATUS OF SLUDGE TREATMENT AND UTILIZATION

Treatment system

Centralized treatment

The sludge generated from 11 wastewater treatment plants is sent by pipeline to two sludge treatment and recycling centers located on the waterfront for centralized treatment. Sludge from the five plants in the northern part of the city is sent to the Hokubu (northern) Center and that from the six plants in the southern part is sent to the Nanbu (southern) Center.

The sludge is pumped under pressure through special pipelines from the WTPs to the sludge treatment and recycling centers. Both centers apply basically the same system of sludge treatment and transportation. This chapter profiles the Hokubu Center.

The sludge generated at the WTP plants is first sent to a sludge conditioning tank where its total solid (TS) concentration is adjusted to 1-2% and then it is pumped to the Hokubu Center.

Thickening process

The sludge pumped from the WTPs first enters the sludge intake tanks and is then transferred to gravity thickening tanks. Next, it is sent to centrifugal thickeners that increase the TS concentration from about 7% to about 5%. Drum screens are used to remove screenings before the sludge is put into the centrifugal thickeners. Centrifugal thickeners were installed in addition to gravity thickeners in response to the decline in sludge amenability to thickening due to putrefaction caused by high concentrations of organic matter and long-term transportation.

Polymer coagulant is added to the centrifugal thickeners in order to maintain a suspended solid (SS) recovery rate of at least 90%.

Digestion process

The sludge is anaerobically digested in egg-shaped tanks, each with a capacity of 6,800 m^3. All are operated as primary tanks in which the sludge is agitated by a mechanical agitator with a draft tube. The sludge has a TS concentration of about 5% when it enters the tanks, where it is digested at a temperature of 36°C and is stored for an average of 25 days. The digestion is therefore of the high-concentration, mesophilic type. When it is removed from the tanks, the sludge has a TS concentration of about 3.5%. The reduction rate for organic matter is about 55%.

Power generation with digestion gas

The gas from the digestion tanks is put to effective use as fuel for gas engines and as auxiliary fuel for incinerators. The gas engines drive power generators that are in constant use along with utility power and provide about 70% of the electricity used in the Hokubu Center.

The exhaust heat from the gas engines is recovered and used to heat the digestion tanks and buildings.

Dewatering process

The digestion sludge is dewatered by centrifugal dehydrators. The dehydrators were adopted because of several advantages, notably the small amount of cleaning water, compact size, ease of odor control, amenability to maintenance and control, and ease of automation of operation. Dewatered sludge cake has a moisture content of about 80%. The TS recovery rate of dewatering is about 90% and the rate of polymer coagulant addition per unit of solids is about 1%.

Incineration process

To reduce disposal volume, almost all of the dewatered sludge is incinerated by fluidized bed incinerators. Two types of incinerators are used, one based on dry desulfurization with calcium carbonate, and the other based on wet desulfurization. Ash from the wet desulfurization incinerators is sent to a soil improvement plant where it is effectively used to improve the quality of soft excavated soil. The ash from the dry desulfurization incinerators is sent to a cement plant outside the city where it is effectively used as raw material for cement.

Sludge properties

In FY 2006, sludge generated from the 11 WTPs was sent to the sludge treatment and recycling centers at an average TS concentration of about 1.43%. The sludge intake at these centers totaled 649 million m^3 for the year. Table 2 shows the properties of the conditioned (thickened) sludge from the WTPs.

Table 2. Properties of Hokubu and Nanbu thickened sludges

pH	5.6
Moisture (%)	98
Ignition loss (%)	78
Mercury alkyl (mg/kg DS)	Not measured
Total mercury (mg/kg DS)	Not detected
Cadmium (mg/kg DS)	0.8
Lead (mg/kg DS)	15
Organic phosphorus (mg/kg DS)	Not measured
Hexavalent chromium (mg/kg DS)	Not measured
Arsenic (mg/kg DS)	3.4
Total cyanogen (mg/kg DS)	Not measured
PCB (mg/kg DS)	Not measured
Copper (mg/kg DS)	170
Zinc (mg/kg DS)	310
Total chromium (mg/kg DS)	Not detected

The Yokohama City Environmental Planning Bureau regulate, monitors and provides guidance on the discharge of industrial wastewater into public sewerage by businesses in the treatment district. This has achieved a much lower content of mercury and other heavy metals in the sludge compared to the benchmark sludge.

Solids balance

The two sludge treatment and recycling centers treat about 106,900 tons of sludge solids per year. Acquiring disposal sites for sludge is difficult in a city such as Yokohama, which has a high population density and is heavily urbanized. Accordingly, Yokohama now adopts various methods for effectively using the entire quantity of sludge as a resource without disposing of any through landfill.

Table 3 presents data on sludge disposal and on effective use of incineration ash.

Table 3. Use of sludge

	Tons DS/year
Soil improvement	7,410 ash
Cement material	10,433 ash
Fluidizing backfilling material	49 ash

Standards related to sludge and waste treatment

In Japan, emissions of soot and smoke from factories and other sources are regulated by law. The incinerators for dewatered sludge installed in the sludge treatment and recycling center are covered by these regulations.

The first piece of legislation aimed specifically at preventing pollution was the Environmental Pollution Prevention Act, which was enacted in 1965. This was followed by the Air Pollution Control Law in 1968 and the Kanagawa Prefecture Pollution Prevention Act in 1978. Exhaust gases from incinerators in Yokohama are also regulated by these laws, which stipulate the emission limits for smoke and dust, sulfurous oxide, nitrous oxide and other pollutants.

Table 4 shows the regulatory ceiling levels and the actual emission levels at the Hokubu Center.

Table 4. Incinerator exhaust gas regulatory ceiling levels and actual emission levels at the Hokubu center

Pollutant	Regulatory ceiling	Actual emission
Smoke and dust (g/m3)a)	0.15	0.014
Sulphureous oxide (ppm)	50	22
Nitrous oxide (ppm)	80	16
Cadmium (g/m3)a)	0.5	0.01
Hydrogen chloride (g/m3)a)	700	6
Hydrogen cyanide (ppm)	10	0.6

a) Standard temperature and pressure

The incineration ash is designated as a type of industrial waste by the Waste Management and Public Cleansing Law. Ash disposed of by landfill must meet the standards for content of heavy metals and other components as measured through the prescribed leachate tests using deionized water. Table 5 shows the regulatory ceiling levels and the leachate test results.

Table 5. Standards and test results (mg/L) for leaching of heavy metals, etc, from incineration ash

Item	Regulatory ceiling levels (by leachate testing)	Measured level
Cadmium and its compounds	0.3	Not detected
Cyanide compounds	1	Not detected
Lead and its compounds	0.3	Not detected
Hexavalent chromium compounds	1.5	Not detected
Arsenic and its compounds	0.3	0.10
Mercury and its compounds	0.005	Not detected
Mercury alkyl compounds	Not detected	Not detected
Selenium and its compounds	0.3	0.19

Table 6. Constituents of calcium incineration ash

Component	Concentration (%)
SiO_2	33.1
Al_2O_3	18.2
CaO	8.9
Fe_2O_3	9.3
MgO	2.8
Na_2O	0.92
K_2O	Not measured
MnO	Not measured
SO_3	0.63
Ignition loss	0.26
pH	7.3

Outline of sludge utilization as resources

In Yokohama, sludge is currently centrally treated and finally incinerated. The objectives of this system include treatment efficiency and ease of environment measures through the economies of scale, more efficient utilization of energy and resources through centralization, and extended life of disposal sites through incineration.

Nevertheless, in light of the future shortage of disposal sites and the need for preservation of the global environment, the city is considering other recycling methods adapted to the various forms of sludge.

Facilities producing construction materials from incinerated sludge ash

After thickening, the sludge generated from WTPs in the northern part of city is sent by pipeline to the Hokubu Center, where it is treated and eventually incinerated. Part of the resulting ash is used as a soil improvement agent. However, the heavy-metal content of the benchmark sludge is considered to be higher than that of the sludge in Yokohama, and it is assumed that this content will be further reduced through tightening of industrial wastewater regulations.

Development of the soil improvement plant

The ash from incineration of sewage sludge is generally divided into two types in accordance with the difference in properties derived, for example, from the kind of coagulate added during dewatering. The two types are calcium (lime) and polymer. At the Hokubu Center, calcium carbonate is added to dewatered sludge to counter the emission of sulfurous oxide from incinerators. The ash therefore has a high content of calcium oxide and has properties similar to the so-called calcium ash. Table 6 shows the constituents of calcium ash in Yokohama.

Research into ways of making effective use of sewage sludge was focused on calcium ash because of its water absorbing and self-hardening characteristics, and hit upon the idea of using this ash as an agent to improve the weak excavated soil from sewerage construction, thereby resolving the disposal problem of both this ash and the residual soil at a single stroke.

Outline of the facilities

Completed in 1987, the plant is the first in Japan to make use of incinerated sludge for soil improvement. At the time of its completion, the plant was capable of producing up to 30 m^3 of improved soil per hour and about 50,000 m^3 per year, but in 2004, additional facilities were installed by means of private funds aiming to expand the usable quantity of incinerated ash and to exploit new land for improved soil. As a result, improved-soil production increased by 70 m^3 per hour and about 110,000 m^3 per year, while effective use of incinerated ash amounted to about 7,000 tons per year.

Operation

The plant uses about 7,000 tons of sludge ash annually to produce about 110,000 m^3 of improved soil. The improved soil is used as backfill material for sewerage pipes and for public construction such as water-supply works and subway works.

On a dry weight basis, about one part of ash is added for every nine parts of excavated soil. Unslaked lime is added in a proportion of about 2% as supplementary material. Efforts are made to ensure that the product has a soil CBR of at least 15% in laboratory tests.

On-site follow-up investigation

As a matter of quality control, the production of improved soil is targeted at a CBR of at least 15% in laboratory tests, as noted above. Nevertheless, it was deemed necessary to monitor any changes in the quality of improved soil used for backfill. To this end, investigations were conducted at backfill sites for three years after execution.

The investigations revealed that the soil improved with sludge ash had essentially the same characteristics as pit sand designated by road works administrators as backfill material in Yokohama.

Furthermore, the improved soil undergoes leachate testing for hazardous substances including hexavalent chromium. The results of analysis are shown in Table 7.

Table 7. Measured levels of hazardous substance in improved soil

Hazardous substance	Measured level (mg/l)
Hexavalent chromium compounds	Not detected
Mercury and its compounds	Not detected
Mercury alkyl compounds	Not detected
Arsenic and its compounds	Not detected
Lead and its compounds	Not detected
Cadmium and its compounds	Not detected
Cyanide compounds	Not detected
Organic phosphorus compounds	Not detected
PCB	Not detected
Fluoride	0.18

FUTURE OUTLOOK AND ISSUES

The production of improved soil currently makes effective use of about 40% of the incinerated sludge ash generated in Yokohama. The effective use of sludge is actively promoted through the production of bricks, the study of horticultural soil and its use as cement material. Since FY 2004, the entire quantity of sludge has been effectively used without disposing of any through landfill.

The improved soil is being used as backfill material primarily for city sewerage construction works and water-supply works. The number of such projects is expected to decline now that urban facilities such as sewage are maintained. Accordingly, in order to expand the utilization routes to other public and private projects, private sector efforts have been introduced for operation of improved-soil plants.

Furthermore, in order to continue stable and effective use of sewerage sludge in the future, new methods of use must be developed. For this reason, sludge recycling methods not limited to incineration must also be considered in order to ensure successful development results.

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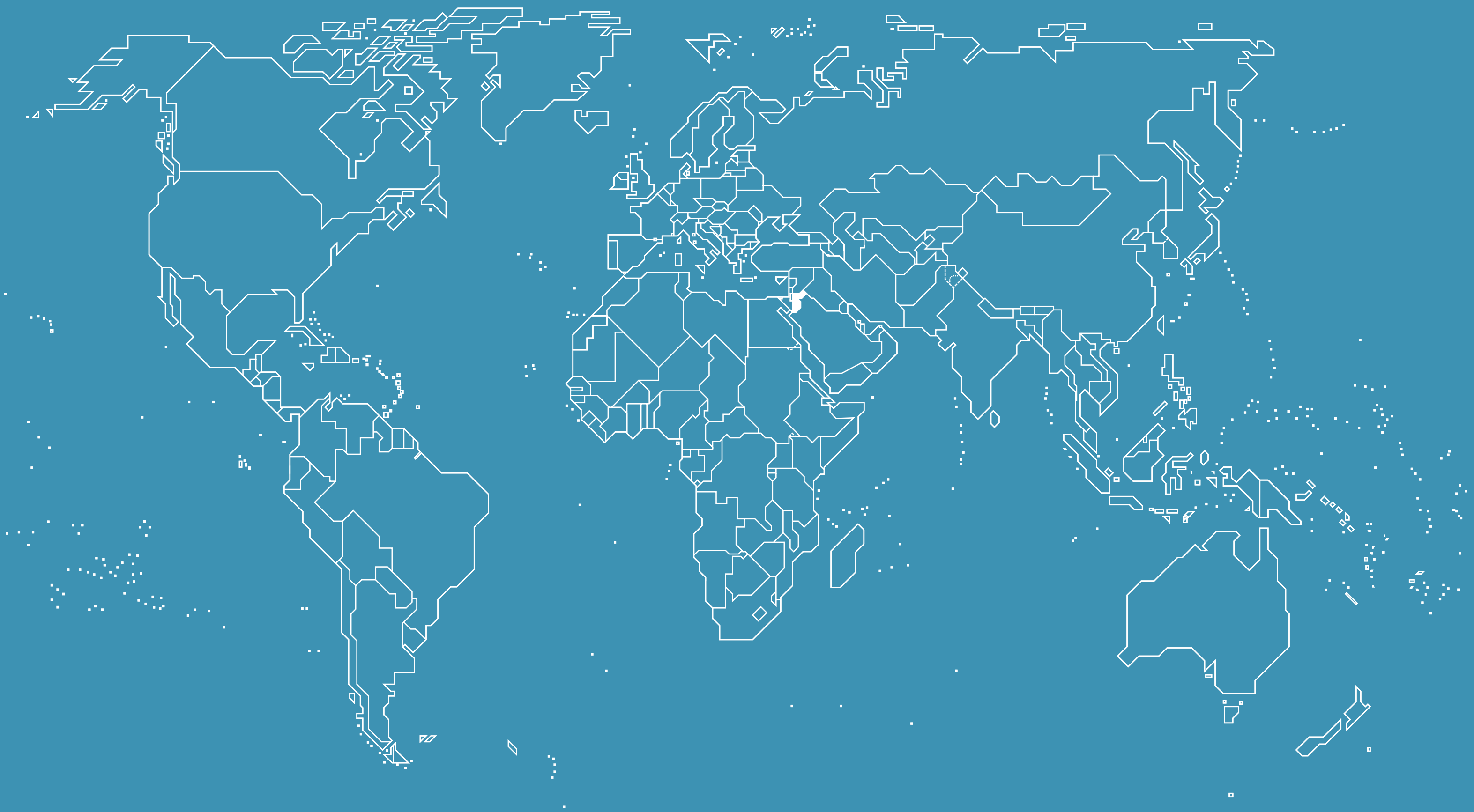

Jordan

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Jordan

OPTIONAL SHORTER VERSION OFR LOCALITIES WITHOUT CENTRALIZED TREATMENT

How much of these materials are managed in your jurisdiction each year? How much additional material is not managed, is ignored, and is untreated and/or untracked? Please describe the population(s) served by the management of these materials.

There are nineteen wastewater treatment plants in Jordan serving around 26 cities (a population of around 3.4 million). About (300,000 m^3) of liquid sludge as well as (11,000 m^3) of dewatered bio-solids are generated annually at the designated treatment plants (Table 1a & 1b).

Table 1a. Sludge production rates and disposal costs

Treatment Plant	Population Served	Disposed/Accumulated Sludge (m^3)	Total Disposal Cost (JD)
As-samra	-	600,000	-
Mafraq	35,000	6,000	55,000
Wadi Al-seer	-	4460	13,000

Table 1b. Sludge production rates and disposal costs

Treatment Plant	Population Served	Liquid Sludge (m^3/year)	Dewatered Sludge (m^3/year)	Total Disposal Cost (JD/year)
Madaba	50,000	50,200	900	110,000
Abu-Nuseir	35,000	29,200	-	16,000
Fuhais and Mahes	23,000	4,380	130	9,000
Al-salt	55,000	27,375	1,825	62,000
Al-baq'a	250,000	91,250	-	91,000
Wadi Al-Arab	200,000	31,000	3,100	41,000
Irbid	70,000	20,000	2,500	159,000
Wadi Hassan	40,000	7,300	730	6,300
Al-Ramtha	40,000	5,000	900	9,000
Jerash	75,000	27,400	600	31,000
Kufranjeh	45,000	11,000	700	25,000

Strategic selection of disposal practice – What is most commonly done with sludge/faecal sludge/septic waste/excrement in your country or region? Does it go to lagoons? Is it put in landfills or incinerated? Is it composted or treated in any way to make it usable on soils? What options are used? Please discuss in order from most common method to least common method.

Bio-solids generated at Municipal Wastewater Treatment Plants (MWTPs) are usually thickened, dewatered using drying beds, then hauled by private contractors to dumping sites, while anaerobic lagoons are occasionally de-sludged for operational purposes, and bio-solids are inadequately stored in nearby areas (Table 2). In other words, none of the bio-solids are currently being reused or recycled (i.e. there are no beneficial usages for sludge and bio-solids in Jordan). However, a new central treatment plant (As-Samra) has included in its plan the treatment and reuse of sludge.

Table 2. Sludge treatment facilities

Treatment Plant	Operation System	Thickeners	Drying Beds	Aerobic Digester	Filter Press
As-Samra	Stabilization Ponds				
Madaba	Activated Sludge	•	•		
Abu-Nuseir	Activated Sludge	•		Unused	Unused
Fuhais and Mahes	Activated Sludge	•	•		
Wadi Al-seer	Aerated Lagoons				
Al-salt	Activated Sludge	•	•		
Al-baq'a	Trickling Filter	•	•		
Wadi Al-Arab	Activated Sludge	•	•		
Irbid	Trickling Filter	•	•	•	
Wadi Hassan	Activated Sludge	•	•		
Al-Ramtha	Activated Sludge	•	•		
Jerash	Activated Sludge	•	•		
Kufranjeh	Trickling Filter		•		
Mafraq	Stabilization Ponds				

How are the decisions made as to what to do with it? Is risk assessment involved? Are decisions driven by cost, practicality, availability of equipment or labor – what drives decisions? Who makes the decisions?

No risk assessment is involved to date, as there is no wide application. However, through a research project, the Royal Scientific Society (RSS) in cooperation with University of Arizona (UoA) initiated capacity building activities concerned with risk assessment for the application of bio-solids. Further, an analytical manual for testing bio-solids "*Analytical Procedures of Sludge and Bio-solids*" was prepared by RSS and UoA with the facilitation of the Badia Research & Development Center (BRDC). This work was accomplished to prepare for further consideration of bio-solids land application in Jordan. Decisions are mostly driven by the health factors and so the bio-solids meet the standards.

Economics are very much a feature of operations, but comparisons can be difficult because of the influence of external factors, for example international exchange rates and the local cost of commodities such as fuel and power. This project is a comparison of practical operations, not of the economic structures of costs. Nevertheless, there is interest in comparative costs and hence we have used commodities as a benchmark which are not only of international relevance, but also contribute to sludge disposal costs. Please give the following in your local currency: What does it cost to dispose or use sludge/faecal sludge/septic waste/excrement?

- The total annual transfer cost of sludge/bio-solids to dumping sites is currently exceeding 627,300 JD ($885,000). Most of the cost is attributed to hauling liquid sludge. This cost is expected to increase dramatically because of the current high oil prices.
- Charge to customers for treating one cubic meter of sewage = $2.3
- Cost of 1000 litres of diesel fuel = $700
- Cost of one kilowatt hour of electricity = $0.062

Please describe the processes of treatment, use, and/or disposal for the most common ways of use or disposal identified above.

The majority of municipal wastewater treatment plants (MWTPs) in the country are of the secondary type, achieving nutrient and pathogen reduction utilizing conventional and modified activated sludge processes that generate relatively huge amounts of Type II bio-solids. Almost all generated sludge and bio-solids quantities at the designated treatment plants are usually disposed of at nearby dumping sites, i.e. there are no beneficial usages for sludge and bio-solids in Jordan.

If it is used in agriculture, please describe how it is managed. Are there requirements regarding the soils receiving the material? What other requirements are there?

No wide application is in place yet. The subject is still in the research phase. A standard (outlined below) has been developed as a result of the research work. The standard includes rate of application to soil according to the quality of the bio-solids and the soil.

If it is used on food crops or on lawns, parks, or playing fields, please describe how it is managed. What measures are taken to prevent contamination or disease transmission? Are there requirements regarding the soils receiving the material? What other requirements are there?

NA

If it is used for land reclamation or in forestry, please describe how it is managed.

NA

If it is placed in landfills, please describe how it is managed.

The following are the processes of sludge disposal for each treatment plant:

Madaba Treatment Plant

Generated liquid sludge is currently disposed of at Ain Ghazal treatment plant, about (45) km away from the treatment plant, while dewatered bio-solids are usually accumulated within the premises of the treatment plant, then periodically hauled by private contractors to As-Samra treatment plant, about (60) km away from the plant.

Abu- Nuseir Treatment Plant

Liquid sludge is currently disposed of at Ain Ghazal treatment plant, about (25) km away from the plant.

Fuheis Treatment Plant

Generated liquid sludge is currently transferred to Ain Ghazal treatment plant, while dewatered bio-solids is usually collected within the premises of the treatment plant then transferred by a private contractor to As-Samra treatment plant.

Salt Treatment Plant

Liquid sludge is transferred daily to Ain Ghazal treatment plant, while dewatered bio-solids are collected and transferred to As-Samra treatment plant.

Baq'a Treatment Plant

Generated liquid sludge is currently disposed of at Ain Ghazal treatment plant.

Wadi Al-seir Treatment Plant

Since the start-up of the treatment plant, sludge accumulated at the maturation ponds was disposed of twice; the first time was in (2003) and the second was in (2005), while anaerobic ponds were desludged only once during (2005). Desludged quantities were stored within the premises of the treatment plant.

As-Samra Treatment Plant

Because of the operation system type, there is no periodic sludge disposal. Two of the anaerobic ponds were desludged during (1996), the desludged amounts estimated at (250,000 m^3) were stored at the plant site. In addition, there are also about (350,000 m^3) of dewatered bio-solids generated at other treatment plants and disposed within the plant premises (Table 1a).

Wadi Arab Treatment Plant

Generated liquid sludge and dewatered bio-solids are currently disposed of at Alakaider dumping site.

Central Irbid Treatment Plant

Generated liquid and dewatered bio-solids are currently disposed of at Alakaider dumping site.

Wadi Hassan Treatment Plant

Generated liquid sludge and dewatered bio-solids are currently disposed of at Alakaider dumping site.

Ramtha Treatment Plant

Generated liquid sludge and dewatered bio-solids are currently disposed of at Alakaider dumping site.

Jerash Treatment Plant

Generated sludge/bio-solids are currently disposed of at Alakaider dumping site.

Kufranjeh Treatment Plant

Generated liquid sludge and dewatered bio-solids is currently disposed of at Alakaider dumping site.

Mafraq Treatment Plant

Anaerobic ponds were desludged in 1996 and 2005. The sludge was buried within the premises of the treatment plant.

Karak Treatment Plant

Generated liquid sludge is currently disposed of at Al-Lajoon treatment plant, while dewatered bio-solids at Karak landfill.

Tafilah Treatment Plant

Generated liquid and dewatered sludge are currently disposed of at Jarf Al-Daraweesh dumping site utilizing Water Authority of Jordan (WAJ) vehicles.

Ma'an Treatment Plant

Anaerobic ponds are usually desludged every five years.

Aqaba Treatment Plant

Liquid sludge is being recycled to the system during winter.

Wadi Mousa Treatment Plant

Liquid sludge generated during winter at Wadi Mousa treatment plant is recycled to the system. In summer, dewatered bio-solids are accumulated at an open storage area within the premises of the treatment plant.

Note: At Alakaider dumping site, there is a facility for the treatment of the solid waste and its leachate. A waste-to-energy project is on the agenda.

Laws and regulations should be summarized as succinctly as possible for each management option discussed above and in the most detail for the preferred option. Does risk assessment underpin these laws and/or regulations? If so, please discuss.

A definite strategy for the beneficial uses of bio-solids, particularly for agricultural land application, is being developed. Different activities carried out in the field of sludge/bio-solids by RSS in cooperation with WAJ, the National Center for Agricultural Research and Technology Transfer (NCARTT) and the bio-solids ad hoc committee have led to the modification of the Jordanian standard No. (1145/1996) for bio-solids reuse in agriculture, in order to be applicable to the conditions of Jordan; the updated standard was formally approved and published in the official newspaper at the end of 2006. The current Jordanian Standard (JS: 1145/2006, Uses of Treated Sludge and Sludge Disposal) took into consideration the following aspects among other issues: the reuse of bio-solids in agriculture; application procedures and rates that are suitable to local conditions; and potential locations for land application.

The following guidelines are stated in JS: 1145/2006:

- It's prohibited to store bio-solids near wadis, areas exposed to floods, irrigation channels, water bodies and sites diversely affect surface water and groundwater.
- It's prohibited to dispose of bio-solids in water bodies, wadis, groundwater recharge areas and wastewater networks, with the exception of wastewater treatment plants receiving wastes from domestic cesspools.
- Bio-solids are added during January and December for productive trees and during September and October for field crops and pastures, the addition process shall take place within one week before planting for irrigated areas.
- It is not permitted to add bio-solids for lands planted with vegetables, for parks, house gardens, green flats, or near residential areas. Also it is prohibited to add bio-solids for areas planted with root crops such as carrots, potatoes, radishes or any other crops eaten cooked or uncooked.

- The addition process should be homogenous; within the amounts needed and the existed elements and nutrients covered by the standard.
  - The addition process for irrigated land is carried out along planting lines, bio-solids are mixed with surface soil (10-20cm), there are no specific addition periods but the addition process shall be carried out within a week before planting.
  - For rainy land bio-solids added before precipitation period (starting in October) and mixed with surface soil, land slope shall be less than 5%.
  - For pastures – as above – but cultivation shall be in contours, bio-solids are mixed with surface soil.
- The bio-solids addition rate depends on nutrients in soil and other elements covered in the standards:
  - The maximum nutrient and element concentrations stated by this standard shall not be exceeded.
  - The user shall investigate the nutrient concentrations in soil and crops need before application.
- Bio-solids to be disposed of at landfills shall comply with the guidelines of the standard.
- For the purposes of this standard, bio-solids are classified into three classes, first, second and third class.
  - First class bio-solids are used for agricultural purposes in modifying soil characteristics.
  - Second class bio-solids are used to modify soil characteristics only.
  - It is permitted to dispose of bio-solids of the first, second or third type in landfills.
- It is prohibited to add bio-solids to soil at a rate beyond 6 ton/ha per a year.
- Tables 3 and 4 show the maximum permitted concentrations in bio-solids in addition to maximum annual rates and accumulation limits for elements.

Table 3. Maximum elements concentrations in bio-solids

		Concentration/ Bio-solids Type		
Parameter	**Unit**	**Type I**	**Type II**	**Type III**
As	mg/kg Dry Weight	41	75	75
Cd	mg/kg Dry Weight	40	40	85
Cr	mg/kg Dry Weight	900	900	3000
Cu	mg/kg Dry Weight	1500	3000	4300
Hg	mg/kg Dry Weight	17	57	57
Mo	mg/kg Dry Weight	75	75	75
Ni	mg/kg Dry Weight	300	400	420
Se	mg/kg Dry Weight	100	100	100
Pb	mg/kg Dry Weight	300	840	840
Zn	mg/kg Dry Weight	2800	4000	7500
TFCC	MPN/g CFU/g	1000	2,000,000	-
Salmonella	MPN/4g	3	-	-
Nematode eggs	CFU/4g	1	-	-
Viruses	CFU/g	1	-	-

Table 4. Maximum annual rates and accumulation, limits for elements addition

Parameter	Annual Addition Rate (kg/ha/365 days)	Maximum Accumulation Limits (kg/ha)
As	1	20
Cd	1	20
Cr	25	500
Cu	35	700
Hg	0.85	17
Mo	0.9	18
Ni	5	100
Se	2	40
Pb	11	220
Zn	50	1000

- Collected bio-solids samples must be representative (composite) and from the last stage of the treatment process.
- Needed laboratory analyses for bio-solids samples must be carried out in accredited technical laboratories and approved by supervising parties.
- The frequency of sampling and chemical, biological and microbiological Analysis are as shown in Table 5 below.

Table 5. Frequency of analysis based on produced bio-solids amounts

Bio-solids produced amount (ton/year)	Frequency of analysis (once a year)
Less than 300	once every one year
300-1500	once every 3months
1500-15000	once every 2 months
more than 15000	once a month

If mechanical dewatering is required typically to facilitate a successful operation, please describe briefly why this is so and the techniques employed.

NA

Equally, please describe any stabilization and or disinfection techniques used to render raw sludge, faecal matter, etc. suitable for use or disposal.

Done by drying bed in most of the treatment plants as mentioned in Table 2.

Please identify any 'hot issues' that could ultimately lead to a modification of the rules and regulations. If changes are planned or are imminent please summarize the changes with planned dates.

Too early to consider this, as the standard has recently been updated.

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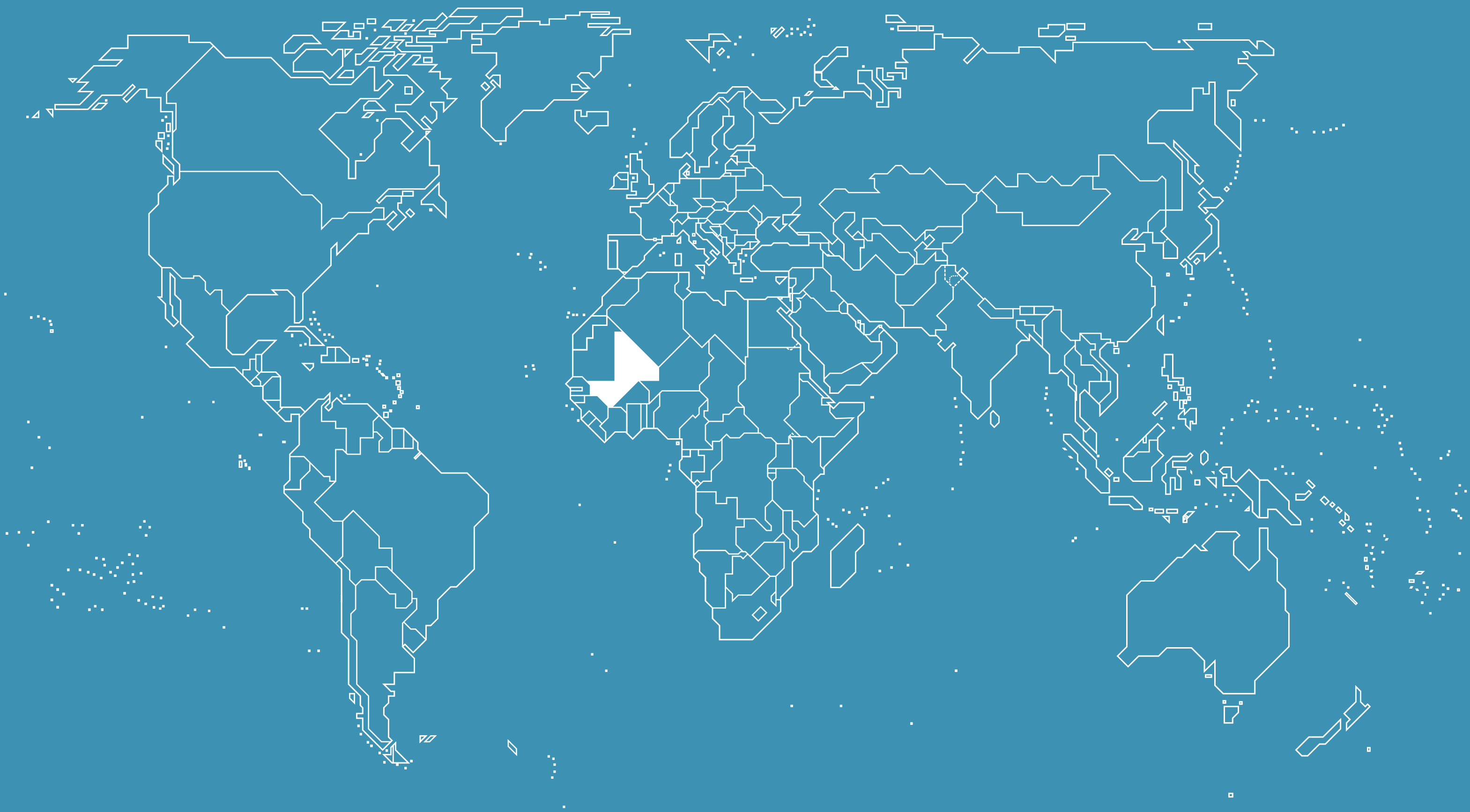

Mali

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Mali

Abbreviations:

DNACPN	*National Department of Sanitation, pollution and Nuisances' Control*
PNA	*National Sanitation Policy of Mali*
ECOSAN	*Ecological Toilet*
EDS	*Social Development Survey*
REFAID	*Low-diameter network*
OMD	*Millennium Development Goals (MDG)*
TAO	*West African Tannery*
VIP	*Ventilated Improved Pit*
WAHODE	*Real Estate Agency*

INTRODUCTION

At the conference on biosolids organised by the International Water Association (IWA) in Moncton (Canada) in June 2007, representatives of IWA, WEF, and EWA agreed that it would be useful to produce a second edition of the atlas published in 1996 and edited the first time by IWA. It was retained that the same format will be used but will be modified/amended to include experiences of the past ten years and modern needs and interests, including the treatment of faecal substances. This edition of the Atlas is sponsored by the United Nations.

The present report is the contribution of UN-HABITAT in Mali to the second edition of the global Atlas on wastewaters treatment and the use of biosolids.

SITUATION OF WASTEWATER AND EXCRETA MANAGEMENT IN MALI

Mali, a vast continental country at the heart of West Africa covers an area of 1 242 238 square km, about 1/24th of the total area of Africa. It has 8 administrative regions and one District which is the capital city, Bamako. The population of Mali is estimated at about 12 millions inhabitants.

In Mali, the populations in urban, peri-urban and rural areas live in very precarious hygiene and sanitation conditions characterised by lack of adequate sanitation services. According to outcomes of the third Social Development Survey (EDS III) in 2001, only 33% of the population in urban areas has adequate sanitation system and only 9% in rural areas.

Generally in Mali, people use individual sanitation facilities including latrines and septic tanks with a secondary treatment pond (cesspools, filtering trench, absorbent cover). Collective and semi-collective sanitation infrastructures are mainly found in Bamako and most of them discharge their effluents into the environment without any treatment. Sludge from individual sanitation facilities is often evacuated inadequately / unsatisfactorily, because these wastewaters are discharged into farms, in ravines or even into rivers without any pre-treatment. Besides, apart from a few industrial units, all others discharge their effluents into the environment without treatment.

Domestic wastewaters and excreta management

Autonomous sanitation

Facilities commonly used include the following:

- Traditional latrine;
- Ventilated Improved Pits (VIP) latrine with either one or two or multiple pits;
- Ecological toilet (ECOSAN); and
- Septic tanks generally endowed with a filter and a manure-spreading device (pit, filtering trench, absorbent cover).

Traditional latrine

It is the most widespread type of latrine in the country. Traditional latrines are found in rural areas and deprived areas in urban centres. It is a makeshift pit dug in the ground and generally covered by a wooden cover with some banjo.

VIP latrine

It is different from the traditional latrine especially because of its superstructure and the existence of a ventilation pipe. VIP latrines with one or two pits are found in households in urban centres.

The VIP latrine with multiple pits is built in schools, markets, car stations and also in administrative buildings

ECOSAN toilet

This latrine is characterised by the separation of urine and faeces. Urine is collected in 20 litre-cans and used to enrich the soil after a stabilisation period of 30 days. During this stay, the urine is disinfected. Regarding the faeces, they are daily treated with ashes or pieces of wood to activate their mineralization. Once the sludge is digested and disinfected, they are used as fertiliser. This type of latrine is in high demand in Mali.

Septic tank and its accessory devices

These facilities are often found in urban centres where there is a water supply network. They are also in households, administrative and commercial buildings and in some schools.

The septic tank generally comes with a filter and a dead well aimed at spreading the treated discharge into the soil. The pit, commonly called a cesspool in Mali, is often badly built.

Due to hydro-geological constraints, more and more septic tanks are constructed as with manure- spreading facilities, filtering trench or absorbent cover (plateau absorbent).

Grey waters in some cases are directly discharged into the cesspool without treatment. Wastes from latrines, septic tanks and cesspools are either manually emptied and poured into gutters and on the streets, or mechanically emptied by 'spiros' trucks and discharged on farms, in streams or empty fields.

In Mali, there are only two experimental stations dealing with sewage wastes treatment: one in Samanko 2 and the second one in Satinébougou. The two stations are mainly made up of anaerobic, optional and maturation ponds. Wastes from these two stations are used as fertilisers after mineralization and the effluents are treated for irrigation.

The Samanko 2 plant, with a capacity of 20 cubic meters a day, has been in use since 2004. The Satinebougou plant is not operational because of lack of a sludge disposal facility, as it is located in a remote area.

Semi-collective and collective sanitation

These infrastructures are mainly found in the District of Bamako. Bamako has about 27 km of classical network, which supplies, among others, the commercial centre and the Badalabougou Sema air base. Effluents drained by these networks are discharged into the river without a final/ definite treatment. In recent years, low-diameter networks (REFAID) have been under development. They drain the wastewaters to a treatment plant. REFAID are generally made up of intermediary pits in houses, an adduction network and a treatment plant. Treated wastewaters are discharged either in backwaters or directly into the river Niger.

Traditional and industrial wastewaters management

In Mali, majority of industrial units/establishments discharge their effluents into the environment without any pre-treatment. Very few, and only a minority of them, treat their wastewaters. They are: West Africa Tannery (TAO), Tannery of Segou, Amitié hotels, Grand Hôtel, and Salam mining companies. Even if these treatment plants exist, very often they are not operational or are not efficient. Industrial units in Bamako discharge more than 31 000 cubic meters a year in the river Niger (Studies of Hamadoun in 1995).

Currently, a treatment plant for industrial wastewaters is under construction in the industrial area of Sotuba in Bamako.

Traditional dyeing is an informal activity exclusively practised by women. This activity is experiencing rapid growth in Mali and especially in the city of Bamako. Dyeing is practised in houses and on the banks of the river or backwaters. This activity discharges more than 16 000 cubic meters of wastewater in the streets and gutters and in streams every year.

DECISION-MAKING

At the institutional level, sanitation is the prerogative of the Ministry of Environment and Sanitation, executed by the National Department for Sanitation and the Control of Pollution and Nuisances (DNACPN) created by ordinance n° 98-027/ P RM of 25th August 1998. The other actors involved in the management of excreta and wastewaters are:

- Families;
- Municipalities, and the
- Government through the following ministries:
  - Ministry of Environment and Sanitation ;
  - Ministry of Mines, Energy and Water;
  - Ministry of Habitat and Urbanism;
  - Ministry of Equipment and Transports
  - Ministry of Health.

The sanitation subsector is supported technically and financially by foreign partners through Non- governmental Organisations (NGO), Associations and others.

The ongoing decentralisation policy in Mali gives an increasing role to municipalities in the sector of water and sanitation supply. Local government takes care of sanitation, whereas the State formulates the policy and monitors its application. The National Sanitation Policy of Mali (NSS) adopted in December 2007 aims at achieving the Millennium Development Goals (MDG). Practically, decisions depend on the importance of the projects. For bigger projects, the State intervenes with its technical and financial partners. This is currently the case of the wastewater treatment plant in the industrial area of Sotuba in Bamako. Concerning projects at municipality level, the local government is in charge of it. DNACPN has a representative in charge of sanitation in each municipality. Concerning individual works, their construction and maintenance falls upon the beneficiaries, indeed the families. In any case, a consultation between all the different stakeholders precedes decision-making. Regulatory and legislative documents define the fields of intervention of each actor.

ECONOMIC CONSIDERATIONS

Costs of equipment

Sludge from latrines and septic tanks are usually emptied by trucks for 15 000 to 25 000 CFA francs per trip. The capacity of the truck varies between 6 and 10 cubic meters. At the family level, the cost of improved latrines and ECOSAN toilets amounts to 125 000 to 350 000 CFA F according to the number of users and construction materials used. The cost of a septic tank varies between 500 000 to more than one million CFA francs depending on the mode of construction, materials used and its capacity. The cost of a cesspool is about 90 000 CFA francs.

One thousand litres of diesel oil is currently 555 000 CFA Francs. In past years the price of fuel has been very unstable. The cost of a kilowatt/hour of electricity varies between 101 and 118 CFA F depending on the section.

Conclusion on the costs

The costs of sanitation facilities are made up of investment charges and maintenance fees. They vary mainly according to the type of work and the materials used.

Compared to the purchasing power of the populations, the costs of sanitation facilities are very high.

TREATMENT PROCESS

One of the most common practices in the management of sludge in Mali is the fact that they are emptied into the environment without any treatment. Excreta from ECOSAN and VIP toilets with double pits are directly used in agriculture. The mineralization of wastes from these works is done in the pits.

The Sludge treatment plant is not operational and yet it is expected that sludge produced from these plants will be used as fertilisers.

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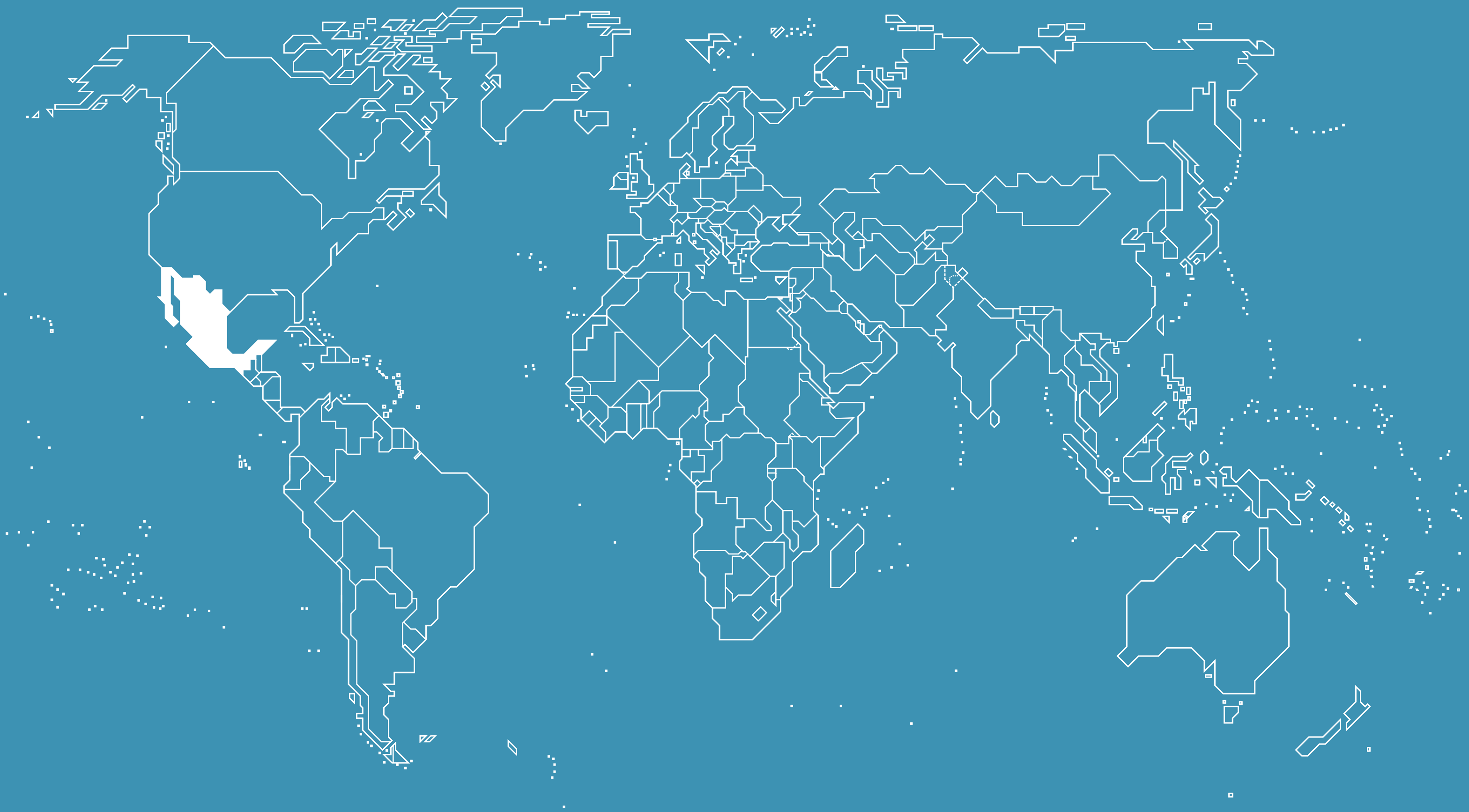

Mexico

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Mexico

WASTEWATER TREATMENT

In Mexico the amount of municipal wastewater produced is 242 m^3/s, while that collected in sewers is 206 m^3/s (85.1%) and treated wastewater is 74.4 m^3/s (30.7%), (CONAGUA, 2007a). This is occurring even though according to Mexican norms (NOM-001-SEMARNAT-1996) and (NOM-002-SEMARNAT-1996) by the year 2005 cities with more than 20,000 inhabitants should have been treating their wastewater, that is to say, nearly 90% of the total wastewater produced.

According to CONAGUA, 2007a, in 2006 there were a total of 1,593 municipal wastewater treatment plants (WWTPs) using the technology presented in Table 1.

Table 1. Wastewater treatment processes and percentage of treated wastewater for 2006 (CONAGUA, 2007a)

Process	% Volume treated
Activated sludge	41.6
Waste stabilization ponds	18.6
Advanced Primary Treatment	13.2
Anaerobic Treatment	2.2
Several processess	24.4

In 2006, non-municipal wastewater, which includes industrial wastewater, amounted to 183 m^3/s. Of this volume only 27.7 m^3/s (15%) was treated in 1,868 WWTPs (CONAGUA, 2007a; INEGI, 2008) using the processes presented in Table 2.

Table 2. Non Processes applied to treat non-municipal wastewater and volume treated for 2006, Data from: CONAGUA, 2007a

Process	%
Advanced Primary Treatment	36.3
Secondary Treatment	54.9
Primary Treatment	3.0
Several processess	5.8

Sludge Production

Considering the amount and type of wastewater treated, municipal wastewater is the main source of sludge. But a large amount of sludge is produced in sewers as well, as a result of solids sedimentation during wastewater transportation in the dry season when velocity in sewers decreases. This amount has been estimated only for Mexico City and is 8.4 million m^3, 14% of which comes from the sludges discharged to sewers from municipal WWTPs (Jiménez *et al.*, 2004a).

Of municipal wastewater treatment, it is estimated that at least 640 million ton/yr (dry basis) of sludge are produced (SEMARNAT, 2008), a quantity that is expected to increase as long as new wastewater treatment plants are put in operation as part of the aggressive program that the federal government has recently put in place to increase municipal wastewater treatment. The amount of sludge thus produced will increase and challenge the need for safe treatment and disposal. But, at the present time, proper sludge treatment and disposal are not current practices, and most of it is discharged into sewers or simply abandoned in soil, threatening health and the environment. In limited examples, sludge is sent to landfills as solid waste and in a few more is applied to the soil, but there is no data on this.

LEGISLATION

Since 2002, the norm NOM-004-SEMARNAT-2002 set guidelines for biosolid quality. This norm promotes the use of treated sludge or its safe disposal in controlled areas. The National Program to Integrally Manage Sludge and Solid Residues establishes a goal to revalorize at least 5% of sludge for agricultural purpose, as a soil amender or to control soil erosion (SEMARNAT, 2008). This will not only imply the need for infrastructure to treat the sludge but also management of it to ensure proper revalorization.

Considering the biological characteristics of biosolids (treated sludge as defined in the Mexican norm), the NOM-004-SEMARNAT-2002 sets three kinds of biosolids classes: A, B and C (Table 3). And, in consideration of the metal content it establishes two types of sludge: Excellent and Good (Table 4).

Table 3. Maximum allowable limits for pathogen and parasites in Mexican biosolids, according to NOM-004-SEMARNAT-2002

	Indicator of bacteriological pollution	Pathogens	Parasites
Class	Fecal coliforms (MPN/g TS)	Salmonella (MPN/g TS)	Helminth eggs (Eggs/g TS)
A	1000	3	1*
B	1000	3	10
C	2×10^6	300	35

**Viable helminth eggs*

Table 4. Maximum allowable limits for the metal content in Biosolids according to NOM-004-SEMARNAT-2002

Type	Excellent (mg/kg)	Good (mg/kg)[a]
Arsenic	41	75
Cadmium	39	85
Chrome	1200	3000
Copper	1500	4300
Lead	300	840
Mercury	17	57
Molybdenum [b]	-	-
Nickel	420	420
Selenium	-	-
Zinc	2800	7500

In order to reuse biosolids, besides fulfilling conditions established in Tables 3 and 4 they need to have a maximum water content of 85%. The types of uses for biosolids are listed in Table 5 depending on their classification. Prior to soil application sludge must also fulfill specific conditions set by the Vegetal Sanitation Federal Law which are determined on a case by case basis (SEMARNAT, 2007 last amended July 26).

Table 5. Uses of biosolids according to NOM-004-SEMARNAT-2002

Type	Class	Use
Excellent	A	Urban use with direct public contact during its application. Same as for classes B and C.
Excellent or Good	B	Urban uses without direct public contact during its application. Same as for class C.
Excellent or Good	C	Forestry uses Soil amender Agricole use

SLUDGE CHARACTERISTICS

In general, Mexican municipal sludge has two common characteristics: (a) a high biological content compared to that found in developed countries' sludge, as presented in Table 6; and (b) its relatively low metal content (Jimenez and Wang, 2006) – a common characteristic in sludge from developing countries. The high content of parasites and pathogens in sludge in Mexico limits the kind of processes that can be used to treat it, requiring one with a high disinfection capability (Jiménez, 2007).

Table 6. Microorganism content in the sludges of different countries (All concentrations are in log/gram of total solids, but helminth ova is in an ova/gram of TS) (Jiménez and Wang, 2006)

Country	Fecal Coliforms	Salmonella	Pseudomona aeruginosa	Bacteri-ophages	Protozoan cysts	Helminth Ova
Germany						<1.1
Australia		2-3				
Brazil	5			<1 – 3	1-3	75
Chile		3.5		2.7		
Egypt					Mean: 1.4, Max 2.6	Mean: 67; Max 735
Mexico	10	7-8	5 – 7	3 – 6	2 – 4 (G)	73 – 177 (V)
France					3	4.4 – 7.7
Ghana						76
Japan	5	1		3 – 4		
Great Britain	4 – 6	2 – 4	3 – 5			< 6
United States	7	2	3	4-6 3(E)	2 (G)	2.0 – 13.0

(E): Enteric viruses (G): Giardia (V): Viable oval

THE PRESENT SITUATION OF SLUDGE AND BIOSOLID MANAGEMENT

There is no data on the total amount of sludge treated in Mexico and most of the WWTPs have no sludge treatment systems. This is a worrying situation due to its potential to pollute water sources and soil. The reason for this situation is that due to the high cost that sludge treatment represents, some cities have already begun their own reuse projects. The cities are shown in Figure 1 and more details on the projects are given below.

Figure 1. Cities where biosolid management programs are in operation or being studied

Ciudad Juárez, Chihuahua

Ciudad Juarez is the capital of Chihuahua state and is located near the border with the United States, adjacent to California state. Chihuahua state has, in total, 116 WWTPs with a capacity for 7.98 m^3/s but is treating only 6.24 m^3/s of wastewater using basically Advanced Primary treatment, Activated Sludge and wetland processes (CONAGUA, 2007b). Ciudad Juarez has around 1.3 million inhabitants (INEGI, 2006). In Ciudad Juarez there are two treatment plants, one with a 2.5 m^3/s capacity and another with a 1.5m^3/s capacity, both using Advanced Primary Treatment processes and producing 86,4000 tons wet basis/yr (17.2 ton/yr, dry basis) of the sludge. At the present time, sludge is dewatered and treated with quick (Jiménez *et al.*, 2003). A research and demonstrative project has been performed to reuse lime-treated biosolids to control sodium salinity in agricultural fields. The results (Table 7) have been very successful in producing cotton and alfalfa, maize and oats for fodder (Uribe *et al.*, 2007).

Table 7. Lime-treated Biosolids application sludge in Ciudad Juarez, Chihuahua, and its potential application to other states of Mexico (Uribe et al., 2007)

Crop	Results	Impact	States where limed biosolids could be applied
Cotton	17% yield increase related to chemical fertilized soil	Benefit/Cost analysis (B/c) is 1.15 with biosolids while when using a chemical fertilizers are of 1.09 de 1.9.	Chihuahua Coahuila Durango Zacatecas Nuevo León
Alfalfa	17% yield increase related to chemical fertilized soil	The economic yield was increased by 12% compared to conventional fertilizer methods	Chihuahua Coahuila Durango Nuevo León Zacatecas Aguascalientes
Oats (fodder)	19% yield increase related to chemical fertilized soil	B/C was 1.42 when biosolids were used instead of 1.14 when chemical fertilizers were applied	Chihuahua Coahuila Durango Nuevo León Zacatecas Aguascalientes
Maize (fodder)	4-88 % yield increase related to chemical fertilized soil depending on the type of soil and the amount of fertilizer applied	The costs of crop production are reduced by 16-27% due to savings on fertilizer costs	Chihuahua Coahuila Durango Nuevo León Zacatecas Aguascalientes

Monterrey, Nuevo León

Monterrey is located in the northern region of Mexico and has a population of 3.6 million inhabitants (85% of the total population of the Nuevo Leon state) according to the página oficial del Gobierno de Monterrey, 2006-2009. Sewerage services are provided to 97.2% of the population and collected wastewater is treated in 3 WWTPs with a total capacity of 8.25 m^3/s and using activated sludge systems (CONAGUA, 2007b). Several projects have taken place to demonstrate the feasibility of applying biosolids to agricultural fields, especially for the evaluation of the metal accumulation in crops. As a result of these studies, Monterrey City is the first city with a registered brand for biosolids known as *Nutriregio®* (Servicios de Agua y Drenaje de Monterrey, IPD 2002).

Tijuana, Baja California

Tijuana is located on the border with California, USA. The city has a population of 966,097 inhabitants (CPTM, 2007). There are 28 WWTPs under operation with a total capacity of 6.4 m^3/s but treating only 4.4 m^3/s. Processes used (ordered by importance) are: Activated Sludge, Advanced Primary Treatment and Oxidation Ditches (CONAGUA, 2007b). The city of Tijuana, together with Rosarito beaches, will be increasing its wastewater treatment capacity by 1.4 $m^{3/}s$. The sludge produced using this new infrastructure will be treated and applied as fertilizers to 37,000 ha of cotton fields in the Mexicali Valley located 210 km away (CESP, 2006).

Sinaloa

Sinaloa has 2.5 million inhabitants (INEGI, 2006). In state has 107 WWTPs in operation, with a total capacity of 4.79 m^3/s and treating 3.82 m^3/s (CONAGUA, 2007b). In Sinaloa, a WWTP (Culiacán North) has an Advanced Primary Treatment processing 116.21 m^3/s of wastewater. The sludge produced is 73.5 m^3/d dried sludge which is being used to fertilize maize fields at a rate of 30,000 ton/yr (dry basis) (JAPAC, 2006).

Toluca, Estado de México

Toluca is the capital of the State of Mexico and it is the highest city in the country, located at 2,680 masl. Toluca is situated 65 km from Mexico City and has 14.4 million inhabitants (CPTM, 2007). Toluca is an industrialized area. It has 78 WWTPs in operation with a total capacity of 7.3 m^3/s but processing only 4.7 m^3/s (CONAGUA, 2007b). The Technological Institute of Toluca has performed several research projects to propose the use of biosolids produced in the wastewater treatment plant of the beer industry to produce flowers. Flower production is one of the main activities in the state, consuming a significant amount of fertilizers and vitamins and increasing production costs. Prior to its application, sludge is dewatered, anaerobically treated and dehydrated (ANUIES, 1999). Sludge has the appropriate characteristics to be used for this purpose.

Mexico City

Mexico City is the capital of the country and is located at 2,240 masl. There are around 21 million inhabitants distributed throughout the Federal District Area (41%) and several municipalities of the state of Mexico (59%).

The part of Mexico City located in the Federal District (where information concerning sludge is available) has a population of 8.7 million inhabitants (CPTM, 2007). It has 30 WWTPs operated by the government and treating 3.53 m^3/s, mainly through biological processes (CONAGUA, 2007b). In Mexico City, several research projects have been performed to reuse biosolids but, so far, the sludge produced is simply discharged into sewers, forming sediments on the infrastructure during the dry season (Jiménez et al., 2004b) or conveyed with untreated wastewater to the Tula Valley (Jiménez and Chávez, 2004).

CONCLUSIONS

In Mexico, an increase in wastewater treatment will pose a challenge in terms of safe treatment and sludge management. This, together with significant soil degradation observed in the country (close to 64% of the total soil surface is degraded according to INE, 2007) creates an opportunity to reuse biosolids. In order to begin a planned programme it is necessary to:

- Perform a national inventory of the production, characteristics, treatment and disposal of sludge and biosolids
- Complete the legal framework for biosolid reuse by aligning application conditions with different circumstances (so far only characteristics for biosolids have been established).
- Determine both technically and economically feasible technologies for disinfecting sludge with high parasite content.
- Develop a communication program about the successful application of biosolids to agriculture.
- Perform training programs to manage, characterize and use biosolids.

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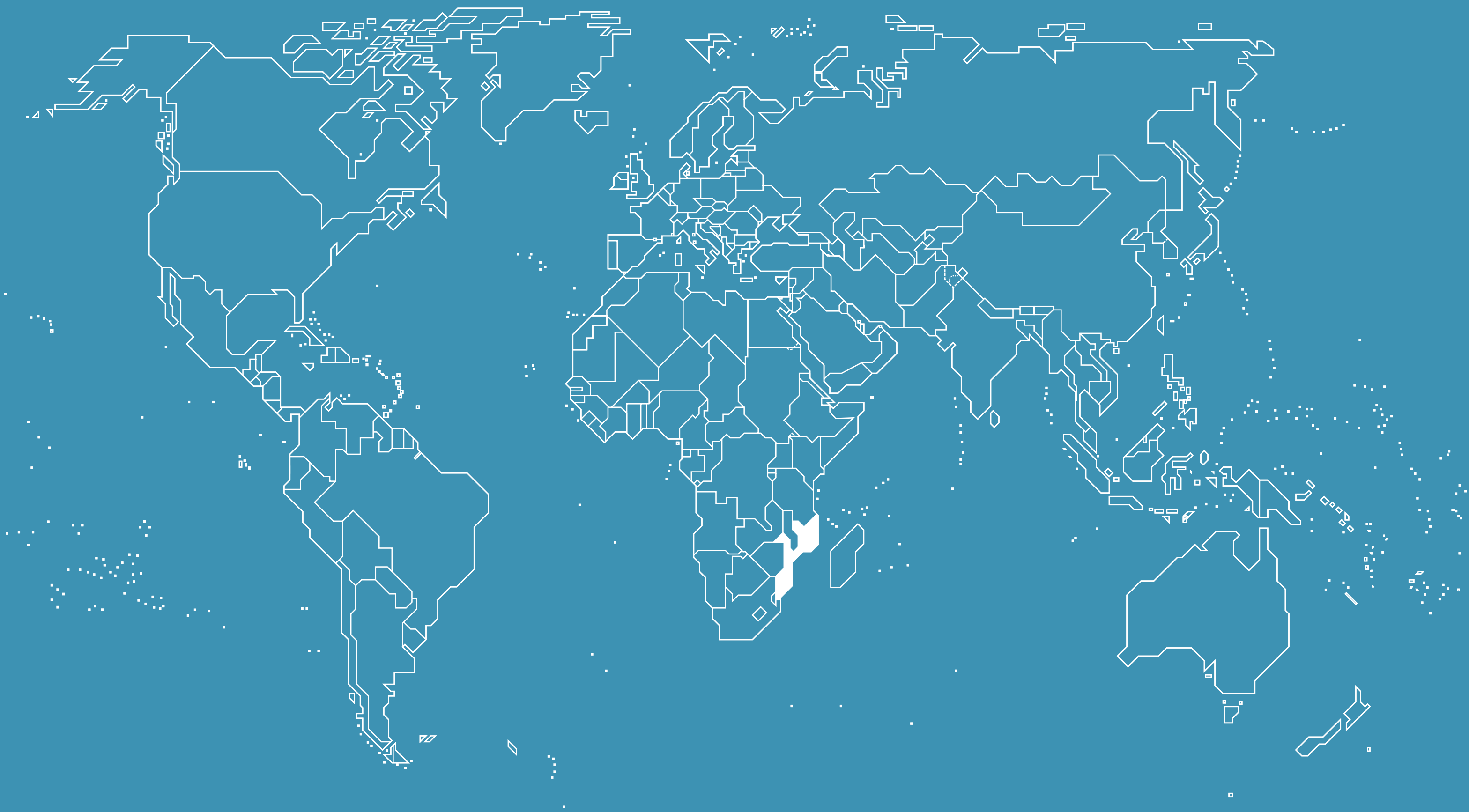

Mozambique

Authors: Mathias Spaliviero, Daude Carimo

Mozambique

INTRODUCTION

At the International Water association (IWA) Biosolids Conference in Moncton, Canada in June 2007, representatives of the IWA, WEF and the European Water Association (EWA) agreed that it would be very useful to produce a second edition of the Atlas, first produced in 1996 and published by IWA. It was agreed that the same format should be used, but modified to reflect experiences of the past ten years and contemporary needs and interests, including the addition of the disposal of faecal matter. For Mozambique, after a general presentation on the institutional, legal and policy context concerning sanitation and particularly wastewater management at the country level, emphasis was given to Maputo, the capital city, for which more data on this topic are available.

LEGAL AND POLICY SANITATION FRAMEWORK IN MOZAMBIQUE

Present policies, existing legislation and regulations relevant for the Mozambican sanitation sector are the following:

- Law on Water Affairs, August 1991;
- National Water Policy, August 1995;
- The requirements regarding the use of land (soil) specified by the Land Act, October 1997;
- Environmental Law, October 1997;
- The Regulation on Public Water Supply, Drainage and Wastewater Systems in Mozambique, approved by the Council of Ministers June 2003;
- The Regulation Environmental Quality and Emissions Standards, in final approval process.

The main institutions directly involved in the preparation and implementation of the referred legislation are:

- Ministry of Public Works and Housing (MOPH) for the Law on Water Affairs, National Water Policy, Regulation on Public Water Supply, Drainage and Wastewater Systems;
- Ministry of State Administration (MAE) for the Land Act;
- Ministry for the Coordination of Environmental Affairs (MICOA) for the Environmental Act and the Regulation for the Environmental Quality and Emissions.

The Municipal Council's tasks and authority are instituted in Law 2/97 (Law 8/97 for Maputo), which comprise public utilities. The Municipal Assembly is responsible for debate and decision on topics of interest for the municipality, for regulations and for monitoring and supervising the activities of the various branches of the Municipal Council; in particular the mentioned legislation enables the Assembly to establish posture codes for solid waste management, sewerage and drainage. Law 11/97 defines the framework for municipality tasks and finances. Article 25 b), in combination with Law 2/97 Articles 6, 1c and Law 2/97, Article 45, institutes the municipality's mandate for water supply, electricity, collection or treatment of wastewater and solid waste management, including tariff setting. Transfer of assets, operation & management and tariff setting authorities to other, public or private institutions, requires the municipality's consent.

The National Water Policy of 1995 outlines the main following long-term objectives with regard to the development of sanitation infrastructure and improvement of services:

- Satisfaction of basic needs by increasing the service grades in general and with special consideration of the poor;
- Participation of beneficiaries;
- Institutional reforms and reorganisation of service provision, following decentralisation policies with the objective to create *"autonomous local agencies"*, which shall become *"financially self-sufficient"*, in combination with capacity building;
- Reduced involvement of the Central Government, which shall concentrate on "setting priorities, direction, definition of minimum levels of service, the collection and provision of information and both stimulation and regulation of the activities of the providers";
- Consideration of private sector participation in infrastructure development and service provision;
- With regard to Urban Sanitation, the objectives include the formulation of "Sanitation and Environmental Master Plans" and "conserving existing urban sanitation infrastructures" and the policy states that "city councils will have a major role to play in the application of a tariff, which should be implemented gradually in parallel with the reorganisation of their sanitation services";
- "In peri-urban areas improved family latrine construction shall be a priority with part of the cost covered by the beneficiaries";
- Pilot Programmes to test solutions for highly populated areas or where the existing technology is not appropriate.

A National Workshop on Sanitation was held on May 12 and 13, 2003 in Maputo, organised by the National Directorate of Water Affairs (DNA), reinforcing the general policies and strategies of the National Water Policy and highlighting following issues:

- Decentralisation and encouragement of the municipalities to establish independent "sanitation services" shall be intensified in line with capacity building;
- Introduction of "sanitation taxes";
- Rehabilitation of central systems and limited expansion, where necessary and financially viable shall be planned;

- High priority shall be given to the increase of coverage of low cost sanitation in peri-urban areas;
- Safe seepage disposal from on-site systems.

CURRENT SANITATION SITUATION IN MOZAMBIQUE

A large migration into the towns and cities of Mozambique, partly as a result of the prolonged civil war, has over-extended the capacity of urban basic infrastructure, originally designed for much smaller populations. For this reason, the existing sanitation and sewage systems, built in colonial times, became obsolete and totally insufficient in relation to the needs of a growing population.

Since the 1970's the Government opted to develop on-site sanitation solutions in order to cover peri-urban and rural areas, in particular through low-cost sanitation. Thus, the improved latrines programme is the main reason for the growth in the overall sanitation coverage by more than 10% in the last decade. However, not much has been invested in sanitation infrastructure, particularly in urban areas, where the matter takes on a complexity of its own, largely linked to the prevailing urban management situation. In fact, more than 80% of the Mozambican cities are constituted by informal peri-urban settlements, and the infrastructural linkage with the built-up part of the cities is difficult to establish. Lately, it seems that this trend is being reversed, with a new priority given to sanitation as a result of formulating new strategies, institutional reforms, and municipal capacity building, with new investments expected soon.

In general, the data on how much of the population is served by adequate sanitation is very disparate. As indicated above, the great majority of the population is served by on-site solutions, improved latrines or septic tanks, or by hybrid solutions, built essentially by private initiative and not effectively listed. In 2005 the proportion of the population with sanitation in the urban and peri-urban areas, according to DNA, was 35%. Other sources indicate more than 50%; this depends on what deemed an "adequate" (or improved) latrine, since a simple hole in the ground without a lid or other covering is not internationally accepted as an adequate solution. The sanitation coverage of the rural population for the same year is estimated at 33%.

The low-cost sanitation programme

Following Mozambique's independence in 1975 the Government identified sanitation as one of the key components in improving health conditions in the country. As such, in 1976, the Ministry of Health launched an intensive national campaign for the self-help construction of latrines. Many thousands of latrines were constructed during a relatively short period. However there were numerous problems with the approach taken, including insufficient awareness about environmental conditions, a lack of technical guidance in latrine design and construction, and shortages of critical building materials. Consequently, many of the latrines became structurally unsafe and unusable, as well as presenting health hazards to the user communities.

In response to this situation, a research project was initiated in 1979 to "identify and develop a suitable technology and method for large scale implementation of improved sanitation in peri-urban areas". The result was the development and successful pilot testing of an appropriate and cost-effective technology, the improved latrine, based on the concept of a simple unreinforced concrete slab, to be placed over existing traditional latrines or over newly excavated three-metre pit latrines.

From 1979 to 1994 it is estimated that 135,000 improved latrines have been produced for peri-urban areas, including opening of production and sales centres and a subsidy system for the poor. In addition an awareness campaign was carried out on the use of the latrine, hygiene promotion, capacity building, etc. In 1996 the programme was extended to the rural areas. Prior to 1998 more than 230,000 latrines were constructed and installed.

The strong aspects of this programme can be summarised as follows:

- It involved a simple technology to build and use;
- The local production and sales centre provided a simple model for scaling up;
- Good grassroots connections and profile were established between peri-urban communities, Government, NGOs and donors;
- The programme progressively developed on its own dynamism;
- Sanitation animators and other promotional work increased demand from 1994;
- Overall, it has been a long, steady scaling up process of more than 10 years.

The weaknesses of the programme were:

- Users had no choice of latrine design; options of a cheaper 1.2 m slab or a pour flush design were introduced later to meet demand;
- Problems of co-ordination between key actors in the sector at national and local level, especially before the Water Policy was designed;
- Staff pay and conditions became a difficult issue to resolve.

In December 1998 the programme was formally transferred to DNA. More emphasis is now given to decentralisation and privatisation, ensuring a progressive withdrawal of the government from the latrine production. DNA remained responsible for the programme only in the city of Maputo.

The introduction of composting and VIP latrines, though relatively low-cost, turned out not to be successful because people do not like the idea of emptying latrines and defecating in a roofed house. Furthermore construction materials are not all available locally and can be expensive. However the solution of ecological latrines, despite some initial reticence, is gradually taking over as definitive solution especially in areas where the type of soil does not allow installing an improved latrine.

Formal infrastructure sanitation

In Mozambique, Maputo is almost the only city with a functioning central sewage system for collection and treatment of domestic sewage. Other important cities in colonial times, such as Beira, Nampula, Quelimane, etc., also have sewage systems but they are not operational.

Beira in particular, in a very flood prone area, suffers from annual cholera outbreaks. An important sanitation programme has started, mainly funded by the European Commission, which will rehabilitate the sewage system in the built-up part of the city.

THE CASE OF MAPUTO

It is estimated that, at present, the Maputo municipal sewage treatment plant serves only 10% of the population and is deteriorating; the old sewer system in the city centre discharges directly into rivers that flow into Maputo Bay. The existing wastewater treatment plant, and the area foreseen for extension and expansion of the plant, is located in the Infulene River valley between Maputo and Matola. The area is prone to flooding and is partly agriculturally used.

About 80% of the population uses septic tanks and pit latrines. Table 1 presents some sanitation data for Maputo city collected in the year 2000; the situation today has worsened.

Table 1. Sanitation data for Maputo, Mozambique

	Population (thousands)
Total	967
Urban	228 (24%)
Informal settlements	738 (76%)
Treatment of wastewater from public sewers	0,2
Sanitation	Population served (thousands)
Public sewers	239
Septic tanks	-
Wet latrines	-
VIP latrines	-
Simple pit latrines	690
Others	-
Total served	929
Total unserved	38

Source: WHO, 2000

Studies in the Maputo Bay revealed that faecal coliforms, faecal streptococci and Escherichia coli were detected in marine water and shellfish tissues. The levels in shellfish tissue were consistently high. The levels of pathogens causing severe gastro-intestinal infections have been increasing over the years. Discharge of untreated sewage has been the main cause of the above mentioned environmental problems, which entail significant socio-economic implications.

Table 2 shows the key environmental impacts regarding the condition, operation maintenance of the existing waste water drainage system in Maputo.

Table 2. Impacts of existing wastewater system, Maputo

Findings	**Impacts and potential risks posed by existing system**
Existing combined systems are old and poorly maintained, often incomplete and leaking.	Leaking of wastewater can cause serious pollution by pathogens and other pollutants; drinking water supply can be affected. Flooding might cause further distribution of pollutants and promote epidemics of infectious diseases such as Cholera, Typhus etc. Old and collapsing sewerage attracts rodents and other vermin.
Most of the installed septic tanks are not maintained.	Poorly maintained septic tanks can cause pollution of receiving water bodies and decreases public hygiene

Findings	Impacts and potential risks posed by existing system
Central wastewater collection serves around 10 % of the population. High percentage of suburbia has no possibility of sufficiently safe excreta disposal	Lack of hygiene raises major concern with regard to public health and water pollution
The treatment plant is poorly maintained and its capacity is not used. No pathogen treatment is installed. Sludge has not been removed since operation started. No monitoring of the treatment plant's effluents is carried out, and the plant's effluents are used downstream for irrigation.	Uncontrolled septage disposal has to be considered serious environmental pollution, in particular water pollution and as potential health risks, since watercourses are used by the population washing and for small-scale irrigation. Uncontrolled distribution of pollutants can spread epidemics of infectious diseases such as Cholera, Typhus etc.

Source: DNA, 2004

The Strategic Sanitation Plan for Maputo, designed in 2004, foresees, up to the year 2017 and under consideration of an increased population of approximately 5 %, a total serving rate of 84%. Safe excreta disposal will be either provided by off-site systems or by septic tanks and latrines.

The planned rehabilitation and extension of the Infulene Treatment ponds (IT P1) will secure compliance with the Mozambique effluent standards and will significantly reduce the pollution and the pathogens discharged (new construction of ITP 2) to the Maputo Bay.

However the implementation of the proposed projects might have some adverse environmental and social impacts. There are generally two types of projects proposed in the Strategic Sanitation Plan:

New construction in city centre and the peri-urban areas, including wastewater system and storm water drainage, wastewater treatment plants and the construction of new sanitary landfills including the access roads.

Rehabilitation and construction of secondary and tertiary sewers and septic tanks are limited in extension and time and adverse environmental impacts are unlikely.

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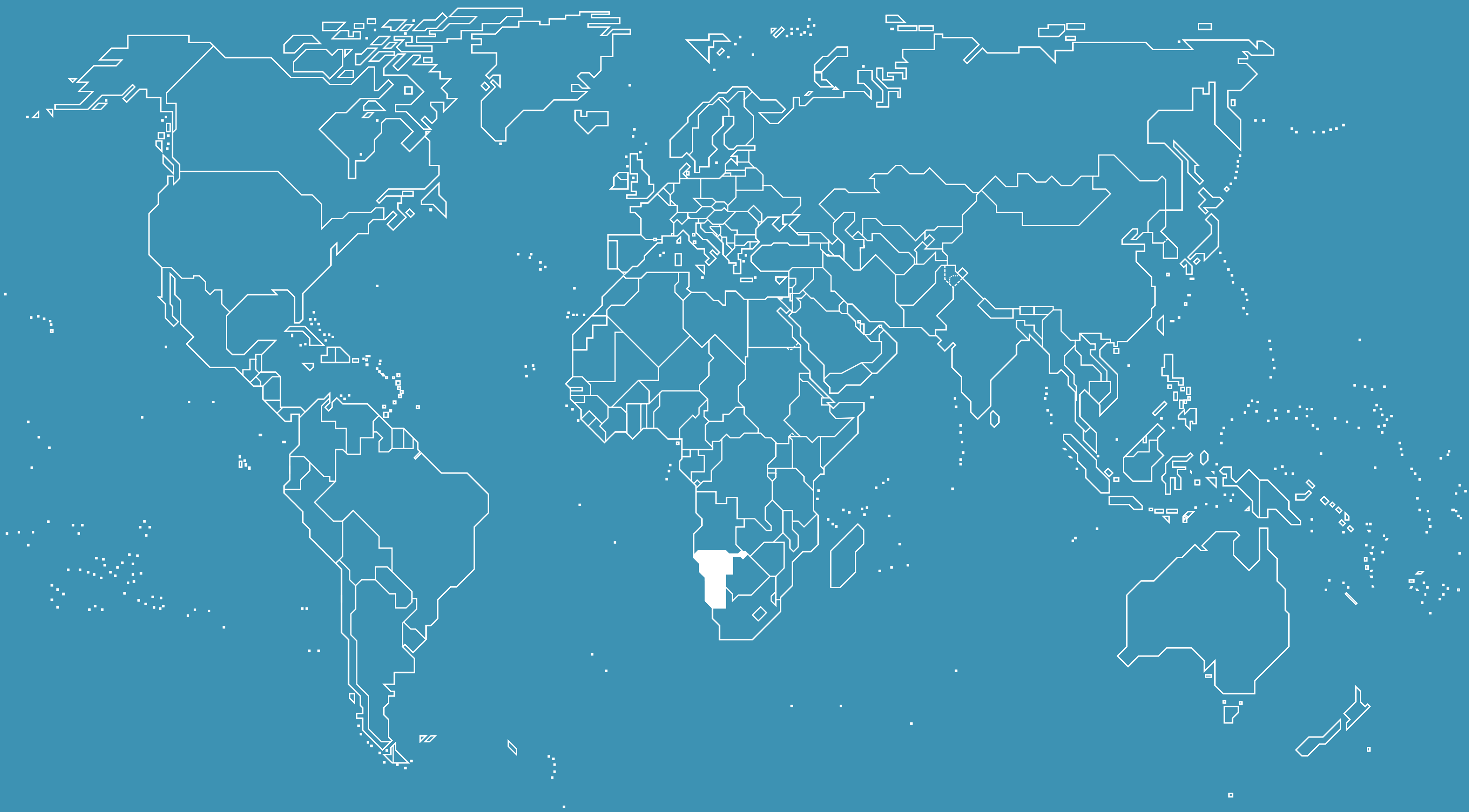

Namibia

Author: Andre Burger

The case of the Walvis Bay Municipality

LOCALITIES WITHOUT CENTRALIZED SEWAGE TREATMENT

This contribution focuses should reflect on experiences of the management of faecal sludge from on-site sanitation units.

Please give the following information regarding the sludge/faecal sludge/septic waste/excrement produced in your country or region within a country:

How much of these materials are managed each year? How much additional material is not managed, is ignored, and is untreated and/or untracked? Please describe the population(s) served by the management of these materials.

Here in Walvis Bay, we only have wastewater sludge. It is treated in anaerobic digesters for 28 days after which it is discharged to dry beds. The disposal/re-utilization thereof is outsourced to a private contractor. Total volume is unknown but can be estimated from the raw sewage volume of around 6500m^3/day.

Strategic selection of disposal practice – What is most commonly done with sludge/faecal sludge/septic waste/excrement in your country or region? Does it go to lagoons? Is it put in landfills or incinerated? Is it composted or treated in any way to make it usable on soils? What options are used? Please discuss in order from most common method to least common method.

After a few weeks' drying, the total volume of dry sludge is crushed by two hammer mills, bagged in 50kg bags and resold mainly to the Municipality for our parks, gardens and sport fields.

How are the decisions made as to what to do with it? Is risk assessment involved? Are decisions driven by cost, practicality, availability of equipment or labor – what drives decisions? Who makes the decisions?

The described method is the traditional way of disposal in Walvis Bay. As the manure is sought-after, relatively cheap compost and the supply equals the demand, no other disposal options have been considered to date.

Economics are very much a feature of operations, but comparisons can be difficult because of the influence of external factors, for example international exchange rates and the local cost of commodities such as fuel and power. This project is a comparison of practical operations, not of the economic structures of costs. Nevertheless, there is interest in comparative costs and hence we have used commodities as a benchmark which are not only of international relevance, but also contribute to sludge disposal costs. Please give the following in your local currency:

What does it cost to dispose or use sludge/faecal sludge/septic waste/excrement?

- No specific costing for the dry sludge management is available as it is outsourced. Total cost of sewage treatment is around N\$3.20/m^3
- Charge to customers for treating one cubic metre of sewage – Based on water consumption, but average at R3.20/m^3 in order to achieve full cost recovery.

- Cost of 1000 litres of diesel fuel – Changing constantly. Expected to increase to R8000 shortly.
- Cost of one kilowatt hour of electricity – R0.6742/kWh

Please describe the processes of treatment, use, and/or disposal for the most common ways of use or disposal identified above.

As described before

If it is used in agriculture, please describe how it is managed. Are there requirements regarding the soils receiving the material? What other requirements are there?

N/A

If it is used on food crops or on lawns, parks, or playing fields, please describe how it is managed. What measures are taken to prevent contamination or disease transmission? Are there requirements regarding the soils receiving the material? What other requirements are there?

Adherence to standards is the responsibility of the private contractor. Ad-hoc tests are conducted by the Health Dept.

If it is used for land reclamation or in forestry, please describe how it is managed.

N/A

If it is placed in landfills, please describe how it is managed.

N/A

Laws and regulations should be summarized as succinctly as possible for each management option discussed above and in the most detail for the preferred option. Does risk assessment underpin these laws and/or regulations? If so, please discuss.

If mechanical dewatering is required typically to facilitate a successful operation, please describe briefly why this is so and the techniques employed.

N/A

Equally, please describe any stabilization and or disinfection techniques used to render raw sludge, faecal matter, etc. suitable for use or disposal.

Chlorine/lime addition for fly combating if and when necessary.

Please identify any 'hot issues' that could ultimately lead to a modification of the rules and regulations. If changes are planned or are imminent please summarize the changes with planned dates.

None

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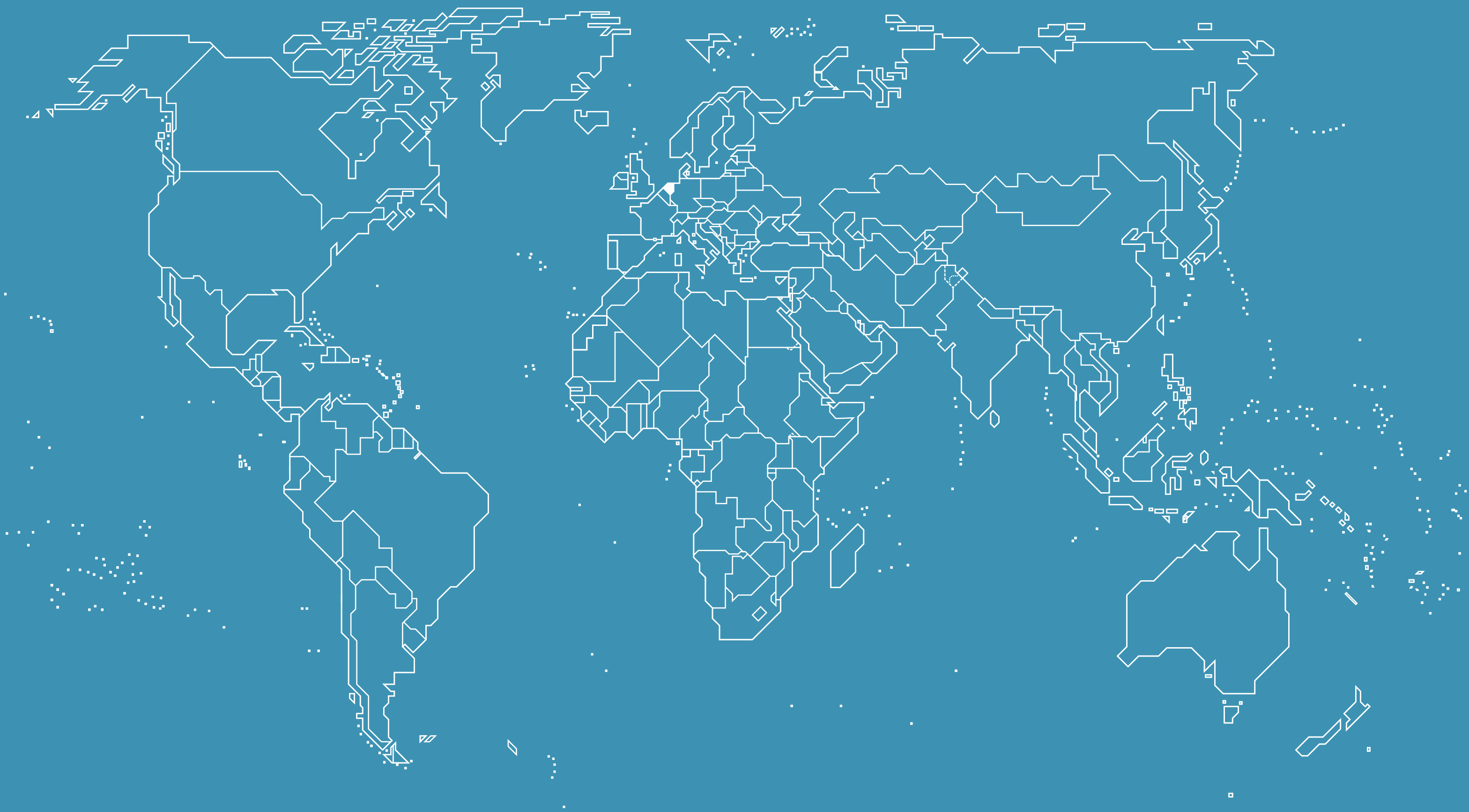


Netherlands

Author: Henk Kreunen

Netherlands

There are 26 Water Boards providing waste water services in the Netherlands.

For the last 20 years, the Water Board Rijn & IJssel has refrained from applying sewage sludge in or on the soil and it has not been used in agriculture. This practice was banned in the Netherlands many years ago.

Increasingly stringent standards for the application of sludge in or on the soil in the late eighties, culminating in a ban, compelled the Water Board to look for alternative methods for processing sewage sludge. The Board decided to dewater all the sewage sludge produced by communal sewage treatment plants and then deliver it for composting.

The sewage sludge is composted by a private third party (the GMB Sludge Processing Company), which has entered into a Public Private Partnership (PPP) with the Water Board. GMB also processes the sludge from 5 other water boards. GMB's two composting plants in Zutphen and Tiel process about 15% of the total (dewatered) sewage sludge produced by communal sewage treatment plants in the Netherlands, which amounts to approximately 1.5 million tons per year (with a total plant capacity of 1,370,000 Resident Equivalents Total Oxygen Consumption). Of the remaining amount, approximately 58% is incinerated and 27% thermally dried. The product resulting from these techniques (composting, incineration and thermal drying) still requires further (final) processing.

Composting involves the biological decomposition of organic material still present in the sewage sludge, while at the same time evaporating the water. The sewage sludge, which is transported on lorries, is mixed in a specified ratio with previously composted material and wood chippings. The resulting mixture is biologically active, easy to aerate due to the wood chippings, and has the moisture level required for an effective composting process.

The blend is then placed in closed tunnels and aerated in a regulated manner for 12 days. The composting process, which begins immediately, releases a great deal of heat, which facilitates the evaporation and extraction of most of the suspended moisture/water. Prior to being exhausted through a chimney, this hot air is cleaned.

After 12 days, the material is removed from the tunnel and sieved. The small amount remaining after sieving undergoes further composting without the addition of secondary agents. Once this process is complete, the moisture content of the resulting granules is about 30%. The average moisture content of dewatered sludge at arrival is approximately 75%. Consequently, the volume of sludge is substantially reduced. The final product, in granular form, is stable and dry, and contains sufficient organic material to make it suitable for a number of different applications.

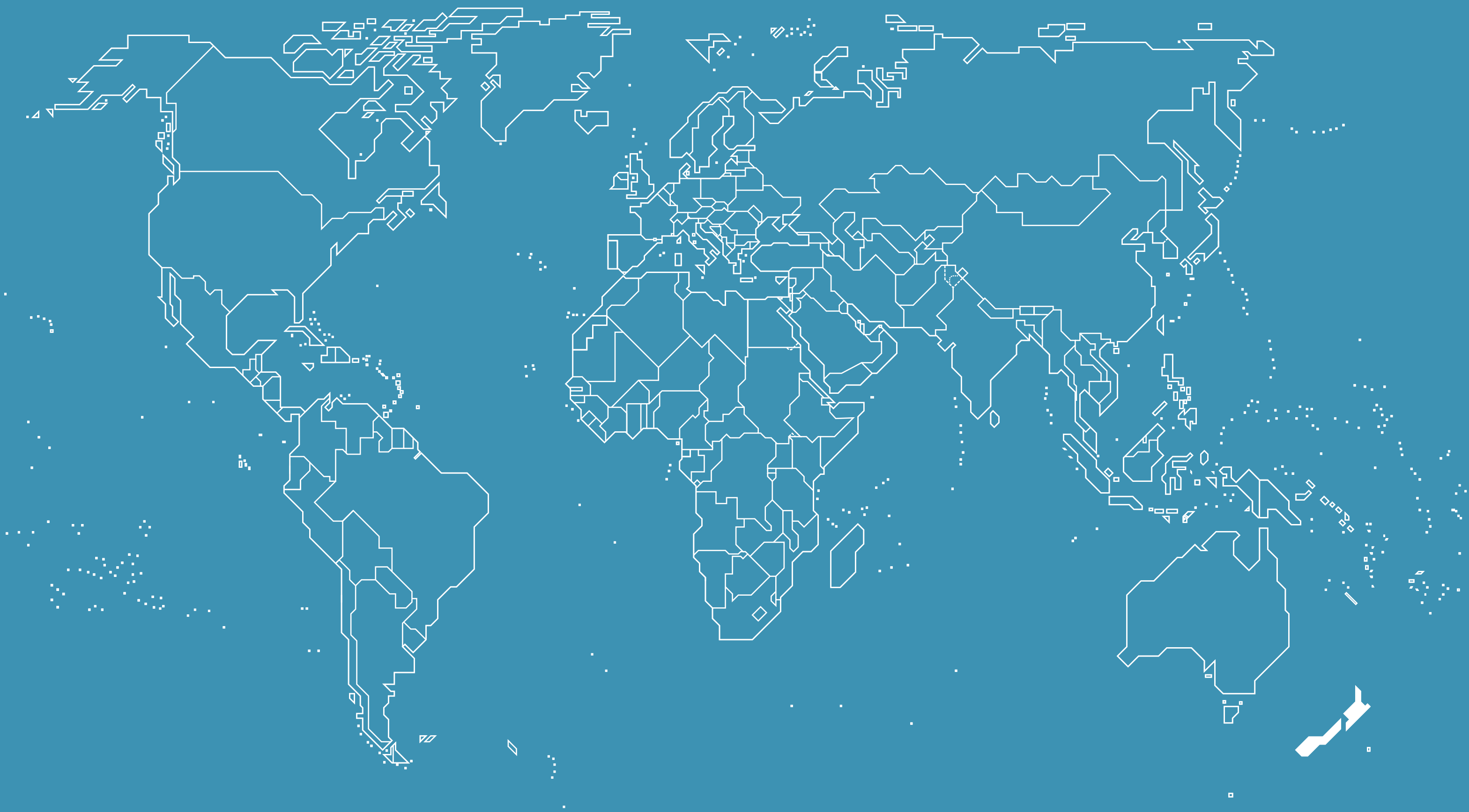
Since 2004, this granular product has been used particularly as a biofuel in power stations, both in Germany and the Netherlands. The granules are used by the power stations either as an additive or as a stand-alone biofuel. This is very likely to be the fate of the benchmark sludge in the Country.

Dutch and European policies are intended to promote the development of useful applications for waste products, an objective clearly reflected in these processes.

GMB has refined the technique of composting sewage sludge to such a degree that it is fair to describe this company as cutting edge. Composting enjoys an availability of nearly 100%: i.e. the processing of sewage sludge is hardly, if at all, restricted by unpredictable situations.

Given the huge efforts by water boards to treat waste water, and considering the investments and/or commitments undertaken to ensure sewage sludge is processed, there is no broad-based support in the Netherlands for reintroducing the application of sewage sludge in or on the soil, or in agriculture.

Furthermore, the Dutch fertilizer surplus means the farming sector is more likely to demand the exclusion of sewage sludge than to welcome its use once more.



New Zealand

Author: Jim Bradley

New Zealand

BACKGROUND

Guidelines for the Safe Application of Biosolids to Land in New Zealand (NZWWA, 2003) contain information and recommendations to assist biosolids producers, dischargers and regulators (regional councils) to manage the discharge of treated domestic sewage to land in New Zealand. Within the guidelines are recommendations for the amount and rate of addition of biosolids to land and criteria for levels of metals and pathogens, which are protective of the environment and human health (see table). A simple biosolids grading system has been developed made up of two parts; the first part which is denoted capital 'A' or 'B' represents the stabilisation grade, the second part denoted by a lower case 'a' or 'b' represents the chemicals contaminant grade. The guidelines have no legal status and the application of biosolids to land is regulated by the Resource Management Act (RMA) (1991) and the Health Act (1956). A resource consent application carries with it a requirement to prepare an assessment of environmental effects (AEE) and in some cases, provides an opportunity for full public scrutiny of the proposal by a public notification process. Sometimes a specific public health risk assessment may be required.

A considerable degree of discussion has taken place on the desirability of a National Environmental Standard for biosolids, a regulatory mechanism under New Zealand's Resource Management Act. Other work priorities for the Ministry for the Environment mean that further development of such a standard is, for the time being, delayed.

Table 1. Stabilisation requirements and maximum concentrations of metals allowed in agricultural soils treated with biosolids

Parameter	Soil limit or ceiling concentrations (mg/kg dry weight)	Biosolids limits Grade a Max. concentration (mg/kg dry weight)*		Grade b Max. concentration (mg/kg dry weight)
Metals		**Until 31 December 2012**	**After 31 December 2012**	
Arsenic	20	20	20	30
Cadmium	1	3	1	10
Chromium	600	600	600	1500
Copper	100	300	100	1250
Lead	300	300	300	300
Mercury	1	2	1	7.5
Nickel	60	60	60	135
Zinc	300	600	300	1500

**Two sets of values are given for this column, allowing for a 10-year transition period to achieve contaminant Grade 'a'.*

Parameter	Soil limit or ceiling concentrations (mg/kg dry weight)	Biosolids limits Grade a Max. concentration (mg/kg dry weight)*		Grade b Max. concentration (mg/kg dry weight)
Pathogens			**Grade A**	**Grade B**
E. coli	NA		<100 MPN/ g	NA
Salmonellae	NA		<1/ 25 g	NA
Enteric viruses	NA		<1 PFU/ 4 g	NA
Helminth ova	NA		<1/ 4 g	NA

**Two sets of values are given for this column, allowing for a 10-year transition period to achieve contaminant Grade 'a'.*

The New Zealand Water and Wastes Association (NZWWA) is the organisation representing, among others, the local government agencies responsible for wastewater treatment and disposal and the subsequent generation of biosolids. National statistics on biosolids generation and use has only in recent years become available – and is still incomplete. NZWWA and the Ministry for the Environment developed a web-based data tool, WINFO, or wastewater information database. Information from that resource informed the figures quoted below.

The following are the available figures regarding biosolids as published in the recent *Environment New Zealand 2007* by the Ministry for the Environment:

- most domestic and commercial wastewater treated at one of the 320 public wastewater treatment plants;
- 234,112 tonnes of sewage sludge generated annually;
- detailed information currently only available from 26 municipal treatment plants, servicing 30% of the population;
- 116,380 tonnes diverted to land reclamation, 79,440 tonnes disposed of to landfill, 36,817 tonnes diverted to other beneficial use, 875 tonnes diverted to pond, 600 tonnes diverted to forest application.

A CASE STUDY OF FOREST APPLICATION – NELSON REGIONAL SEWERAGE SCHEME

Introduction

Nelson Regional Sewerage Business Unit is a joint venture sewerage treatment and disposal scheme owned by the Nelson City Council and the Tasman District Council at the top of the South Island, New Zealand. The treatment plant is located on Bells Island in the Waimea Estuary. Following a major upgrade of the treatment facility in 1995/96 a system was set up to apply biosolids to forestry (*Pinus Radiata*) on a neighbouring Rabbit Island (1100hectares, of which 750 hectares is available for biosolids application). The facility treats a population equivalent of about 120,000, of which between 40 and 50% is industrial.

Application equipment

The biosolids is treated to Class A USEPA sludge standards by an Autothermal Thermophillic Aerobic Digestion (ATAD) plant. The sludge is then pumped via a 3km pipeline across the estuary, to a storage facility centrally located on Rabbit Island. The biosolids is then transported with converted milk tankers to the forestry stands. The tankers are parked on the side of access roads and the biosolids is pumped to a rubber-tracked vehicle known as a "Maggot" that is fitted with a hose reel on the back and an irrigation nozzle on each side of the front crash bars. The Maggot drives into the forest and is capable of spraying up to 35m either side of the path.

Table 2. Biosolids Characteristics

The following characteristics are an average for the past year:		The following are the background soil values:	
Dry Solids	2 %w/w	Zinc	18.2 mg/kg
Organic Matter	n/a	Copper	3.5 mg/kg
Zinc	900 mg/kg	Nickel	21.5 mg/kg
Copper	450 mg/kg	Mercury	<0.05 mg/kg
Nickel	34.6 mg/kg	Cadmium	<0.1 mg/kg
Mercury	1.5 mg/kg	Lead	4 mg/kg
Cadmium	2.5 mg/kg	pH	5.2
Lead	70 mg/kg		
Total Nitrogen	11.0 %w/w		
P205	n/a		
K2O	n/a		

Economic information

Annual operating cost for the plant is $NZ4.5million (operational and finance charges), of which about 10% is for the biosolids application programme and equates to an application cost of approximately $NZ16.00/m^3 of biosolids applied.

- Treatment cost of effluent is approximately $NZ0.95/m^3
- 1,000 litres of diesel fuel currently costs $NZ1,300.

Results

An experimental research trial was established within the plantation in 1997 to investigate the effects of biosolids applications on tree growth, nutrition, and the ecosystem. Biosolids were applied to the trial site in 1997, 2000 and 2003, 2006 at three application rates: 0 (control), 300 (standard) and 600 kg N ha^{-1} (high). Three stocking density treatments, i.e., subplots of 300, 450 and 600 stems ha^{-1}, were included within each biosolids treatment main-plot. Continuing significantly increased growth of *P. radiata* has been observed on the biosolids research trial site at Rabbit Island in the past year. In August 2007 at age 16 years, the mean basal area (BA) of trees in the high biosolids treatment was 40% greater than the control, and that in the standard treatment was 29% greater than the control. Stem volume of the high treatment was 41%

greater than the control treatment, and that of the standard treatment was 30% greater than the control treatment. Although, the relative improvement of stem volume increment in biosolids treatments over the control has been lower in the past year than in previous years, this could be more due to the natural sigmoidal pattern of growth than to a decline in response to treatment. The October 2006 biosolids application has led to a significant elevation in foliage nitrogen concentration compared with the previous assessment. At higher stocking rates, competition has led to significantly smaller diameter trees. However, the higher stocked plots have significantly greater per hectare BA and volume than the lower stocked plots. Tree stocking rates had no significant effect on mean top height. Further monitoring on foliage nutrient and tree growth responses has been recommended.

A CASE STUDY OF BIOBOOST® – NEW PLYMOUTH DISTRICT COUNCIL

Introduction

In 1999, New Plymouth District Council installed a thermal drying facility at its Waste Water Treatment Plant to address the issue of pathogens in its waste water solids and to produce a biosolid suitable for beneficial re-use. This biosolid is marketed as Bioboost® and is sold as a natural organic fertiliser. The New Plymouth Wastewater Treatment Plant treats a population equivalent of approximately 75,000, of which approximately 20,000 are industrial.

A rotary dryer, with direct gas firing, evaporates the water from the plant sludge to produce the thermally dried biosolid. End product temperature is controlled to above 80° C and the final product has less than 10% moisture content. At this temperature and with a contact time of 20 to 25 minutes, a sterile, desiccated biosolid is produced. The rotary drum causes the biosolid to form into pellets, which are controlled to between 2 and 4mm in diameter. The end result is a palletised dry fertiliser that is safe, stable and has excellent application characteristics.

The market

New Plymouth District Council sells the bulk of the production of biosolids to a local company Bioboost® Ltd. that has expertise fertiliser applications, spreading and distribution. The majority of fertiliser is distributed and sold in bulk to businesses such as golf courses and for maize cropping. A small percentage is sold in 25kg bags and currently retails for $NZ15 per bag,

Biosolid characteristics

The council has invested a great deal of resources, via its trade waste programme, in managing industrial discharges and reducing contaminant levels. Currently, industries are at their lowest possible contaminant levels, with the majority of the remaining contaminants being derived from the domestic sector of sewage.

Copper and zinc contaminants are primarily from the leaching from domestic plumbing. The council is presently addressing the corrosiveness of the domestic water supply.

On the rare occasion that the product does not meet its specification, it is quickly identified through routine sampling by our onsite accredited laboratory and sent to the landfill for disposal.

Table 3. Typical characteristics over 2007

Biosolids:		
Average Solids	92	%
Organic Matter	67.8	%
Zinc	510 to 620	mg/kg dry weight
Copper	170 to 240	mg/kg dry weight
Nickel	30 to 55	mg/kg dry weight
Mercury	1 to 2	mg/kg dry weight
Cadmium	< 1	mg/kg dry weight
Lead	30 to 40	mg/kg dry weight
Nitrogen	6	%
Phosphorus	3.25	%
Potassium	0.14	%
Size: 2 – 4mm diameter	80 to 90	(% Wt/Wt)

Economic information

Converting sludge to biosolids costs approximately $NZ132 per wet tonne, an increase of approximately 50% from when sludge was disposed to land. The benefits are, however, that we are saving on landfill cost and space, have a more sustainable process, and can potentially recover a significant portion of the costs.

Although the return now made on Bioboost® does not offset the production cost, the goal is to make the process more economical in the long term by moving the market from bulk distribution sales to selling all product in bags.

Results

Currently, the council meets the 'Guidelines for the Safe Application of Biosolids to Land in New Zealand' for grade Aa Biosolid, for all contaminants with the exception of zinc. Zinc levels are marginally over the present 600mg/kg (dry weight) target due to leaching of domestic plumbing fittings. We are investigating this and looking at ways to further reduce the zinc levels.

The council supports these Guidelines, however, does not support the proposed lowering of Aa grade to proposed 2012 contaminant levels. This will see acceptable levels of zinc decrease from 600 to 300 mg/kg, and copper from 300 to 100 mg/kg. The implications of this would result in unachievable levels and the fertiliser would no longer be able to be marketed as an Aa grade product. Should this become a national standard, the biosolids distribution will cease.

The fertiliser should be applied in line with the "Guidelines for the Safe Application of Biosolids to Land in New Zealand". When used at the correct agronomic nitrogen rates of no more than 200kg total nitrogen per hectare, it can be safely and sustainably applied.

Bioboost®, when sold in the competitive fertiliser market, shows good demand as a slow release fertiliser and has established a regular customer clientele.

Future challenges on the horizon include developing the bagged market further and tackling the 'faecal phobia' response. Our experience with this is that once people see, use and understand the product, these phobias are quickly dispelled. The New Zealand Ministry for the Environment has set a target for 95% beneficial reuse of biosolids, a target that the council currently meets. However reduction further of allowable contaminant levels threatens to torpedo this. Faecal phobia by many regional councils, and their disregard for the science upon which the "Guidelines for the Safe Application of Biosolids to Land in New Zealand" are based has meant the goal of 95% beneficial reuse of biosolids has not been realised in New Zealand.

BIOSOLIDS RESEARCH IN NEW ZEALAND

In New Zealand biosolids research is driven by the "Waste Strategy 2002", which specifies that "more than 95% of municipal biosolids and commercial organic wastes currently disposed of to landfill have to be composted, treated for methane emission, or beneficially used". There are currently two Government (Foundation for Research Science and Technology [FRST]) funded research programmes investigating re-use options for biosolids in New Zealand. These are the SCION "Waste to Resources" and The Institute of Environmental Science and Research Limited (ESR) "Safe and Beneficial Use of Biosolids (Sewage Sludge) on Land" research programmes. Both programmes involve significant collaborations with national and international research providers including Lincoln, Canterbury, Waikato and Massey Universities, Landcare Research, NIWA, HortResearch, AgResearch, National Biosolids Research Programme (Australia), Sewage Sludge and Soil Fertility (UK) and variety of Local and Regional Councils and community groups.

The principle goals of the "Safe and Beneficial Use of Biosolids (Sewage Sludge) research programme are to:

- understand the environmental fate and effects of chemical (heavy metal) and microbiological contaminants from biosolids "beneficially" applied to land.
- understand the social and cultural drivers that influence community perceptions and acceptance of biosolids land application.

The principle goals of the "Waste to Resources" research programme are to:

- identify optimal waste management solutions that will improve sustainability by transforming wastes (municipal & wood-based sectors) into renewable resources, and to study the risks associated with this process
- Investigate sustainability by balancing different outcomes driven by economic, environmental, social & cultural acceptability.

Research results are disseminated through end-user meetings and The New Zealand Land Treatment Collective (the 'NZLTC'). The LTC membership represents governmental agencies at all levels (local, regional, national), and private industry. The organisation was established to support the extension of research into the treatment of wastes and waste products by land application, providing its members with the most recent information on land treatment technology, research and information.

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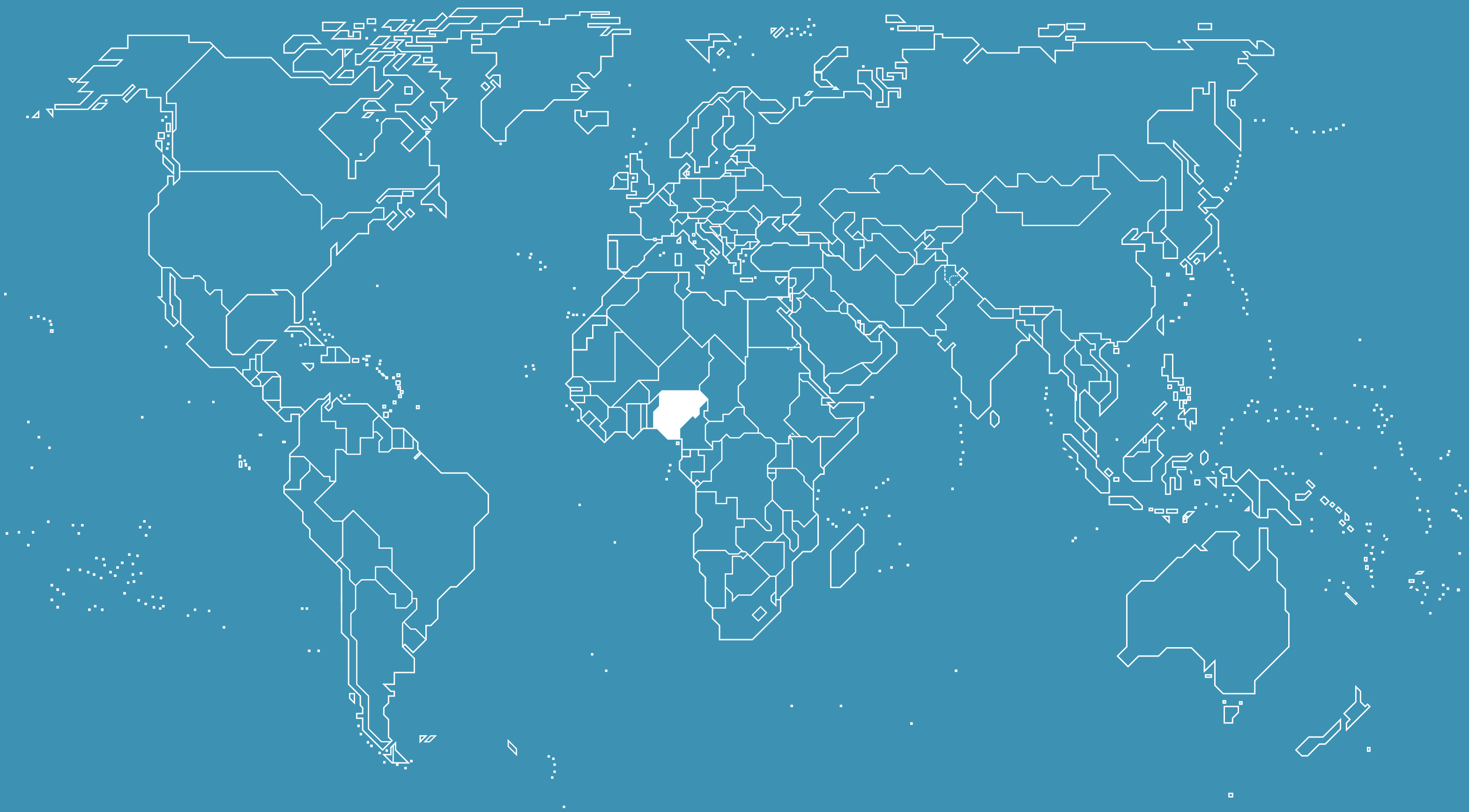

Nigeria

Author: Ibrahim Dibal

Plateau State

CONTEXT

Nigeria is a federation consisting of 36 states plus a federal capital territory of Abuja. It has three tiers of government: the federal government headed by the president; the state Government headed by governors, local government headed by chairmen (one each for the 744 local government Areas). The capital territory is headed by a minister. All the heads of the government are elected into office.

The current UN-HABITAT project in Nigeria, the water for African cities, phase II programme is situated in Jos, capital city of Plateau State. Therefore, this report relates to Jos and surrounding area. Jos city occupies an area of about 1300 square kilometers with a population of 737,016 (Federal republic of Nigeria official Gazette, May 2007)

OVERVIEW OF WATER SUPPLY AND SANITATION SERVICES IN NIGERIA

It is estimated that 60%, or about 78 million Nigerians, did not have access to improved water sources in the year 2002, while 62%, or about 82 million, did not have access to sustainable improved sanitation. Due to lack of reliable data on the existing water and sanitation situation in the country, figures being quoted on the service coverage are only estimates.

Apart from the new Federal capital city – Abuja – and some small isolated areas of Lagos, there are no central sewage systems in any city in Nigeria. The most common domestic waste treatment method is the use of individual septic tanks and soak-away systems.

The State water supply Agencies meet less than 50% of the urban water supply demand. The most common source of water supply to the urban poor is the open well, while hand pump-operated boreholes are usually provide by the State Government.

STRATEGIC SELECTION OF DISPOSAL PRACTICED

A recent consumer altitude survey on water supply and sanitation services carried out in Jos city, showed that about 60% of the population uses the Pour Flush toilet system. This system consists of a squatting pan connected to double compartment septic tank via an S-trap and short pipe to a soakage pit. Most of the waste is digested in the septic tank while the effluent seeps into the surrounding soil in the soak-away pit. The sludge deposit in the septic tank and is de-sludged at intervals depending on the number of users in the household. But de-sledging intervals varies between one to three years. The sludge materials are therefore not managed centrally but at household levels. No survey/study has been conducted in Jos to ascertain statistics. However, the population of Jos city of 737,016 and 60% population would mean that about 442,210 people produce sludge materials from pour-flush type toilets. Scavengers apply the septic waste materials to farmlands, add to compost or dump it in open trenches away from residential houses. The State Ministry of Environment and Housing and the Plateau State Environmental Protection and Sanitation (PEPSA) are authorities in charge of the strategies-setting policies and reforms in the Sanitation section.

The Strategies being pursued include:

- a demand for a responsive approach where end-users decide on what type of facilities they want, bear part of the cost of construction, manage and maintain them with support from their Local Government Councils,
- a decentralized approach where grants are given to districts for implementation and operation of District Water supply and sanitation Development grants,
- adoption of an integrated approach in the management of water resources, liquid and solid wastes, safeguarding of health and protection of the environment, and
- ensuring sustainability in water supply and sanitation services delivery through the community-based maintenance system.

DECISION MAKING

Involvement of risk assessment

There are a number of legal and regulatory frameworks in Nigeria that directly or indirectly affect water supply and sanitation provision to the urban population.

The legal and regulatory tools developed for management of water resources in Nigeria include the following:

- The Water Resources Act, which regulates the use of water resources affecting more than one state and empowers the federal Government to control and regulate the use of water sources affecting more than on state,
- The River Basin Development Act, which divides the country into river basins and establishes River Basin Authorities and gives them power to manage the water resources in their area of jurisdiction,
- The Navigable Water Ways Act, which declares and lists rivers that are considered to affect more than one state and creates the Water Ways Authority and gives it power to regulate the activities in certain specified waterways,

- The State Water Supply and Sanitation Agencies Law, which is a state Law that creates the state water supply agencies, or board or corporations, and charges them with the responsibility for water supply (and sanitation in some states) in their areas of operation, and
- Local Government Water and Sanitation bylaws, which allow a local government to supply and regulate water supply in its area of jurisdiction.

Legislation on environmental sanitation includes:

- Federal and State Environmental Protection Agency Act and Laws establishing regulating agencies at the Federal and State level respectively,
- The Environment Impact Assessment Decree no. 86 of 1992, which makes it incumbent to carry out environmental assessment on every major project,
- Harmful (Toxic) Waste Criminal Provision Decree no. 42 of 1988, which regulates the discharge of harmful substances,
- The Nigerian Urban and Regional Planning Act, and
- The National Agency for Food Drugs Administration and Control (NAFDAC)

The Nigerian National Policy on Environmental Health Practice provides that every tenement should house its septic material in a standard septic tank with a soakage pit.

All decisions on the uses and disposal of sludge are governed by the legislation Acts and bylaws mentioned above.

By what are decisions driven?

Decisions are driven by demand and availability of resources. The strategy mentioned above and the policy being designed by government is all in an effort to attain the MDGs objectives.

Who make decision?

All decisions related to water supply and sanitation are made by the Federal, State or Local Government, depending on the law separating their powers. State Governments can negotiate funds with financial institutes to realize projects related to the improvement of water supply and sanitation, but such funds have to be guaranteed by the federal government.

ECONOMICS

Cost of disposal

By the use of cesspool vehicles, septic tanks are emptied at an average cost of USD$45.00 and disposed crudely without tertiary treatment and/or risk assessment. The cost of diesel fluctuates but currently, it costs USD$935.00 for 1000 litres of diesel fuel. Cost of one kilowatt hour of electricity is USD$35.00.

PROCESSES OF TREATMENT, USES, AND/OR DISPOSAL

Treatment is done at household levels in septic tanks or pits and digested contents are emptied and disposed of crudely, after which scavengers source for manure. It is used in Agriculture. No standards or requirements are applied in managing it. It is basically used on food crops. It is neither used in land reclamations nor forestry. It is not placed in landfills.

Laws and regulations regarding siting of septic tanks and latrines emphasize the following:

- Distance from wells and other water sources – at 30 metres (minimum) away from water source.
- Design with regard to septic tank lifespan, taking into cognizance the number of uses and discharge per head per day.

Preferably, a centralized sewage treatment plant is required for the region, however, lack of adequate and regular water supply and funds for infrastructural development of sewage system mitigate against introducing the centralized system now. For this reason, the best option left is the use of septic tanks with soakage pits.

Laws and regulations should be directed at mandatory provision of water carriage systems or pour-flush into septic tanks.

No stabilization or disinfection techniques are used to render the sludge suitable for use or disposal.

There is the need to have properly designed sanitary landfill sites where dewatering of sludge could be practiced using drying beds or mechanical means.

Many tenements lack latrines, thus, occupants of such tenements resort to open/bush defecation. A few others have water carriage and pour-flush systems, however, the use of these are often hampered by inadequate and regular water supplies.

With the majority of the tenements in the region resorting to simple pit latrines, conversion to water carriage system is eminent so as to avert the attendant health risks of the simple pits and/or open defecation.

REFERENCES

So far the officially accepted census in Nigeria is the one conducted in 1991, which gave the total population of 88.5million and a projected growth rate of 1.86% per annum. Based on this, the 2005 population is estimated to be 130.8 million.

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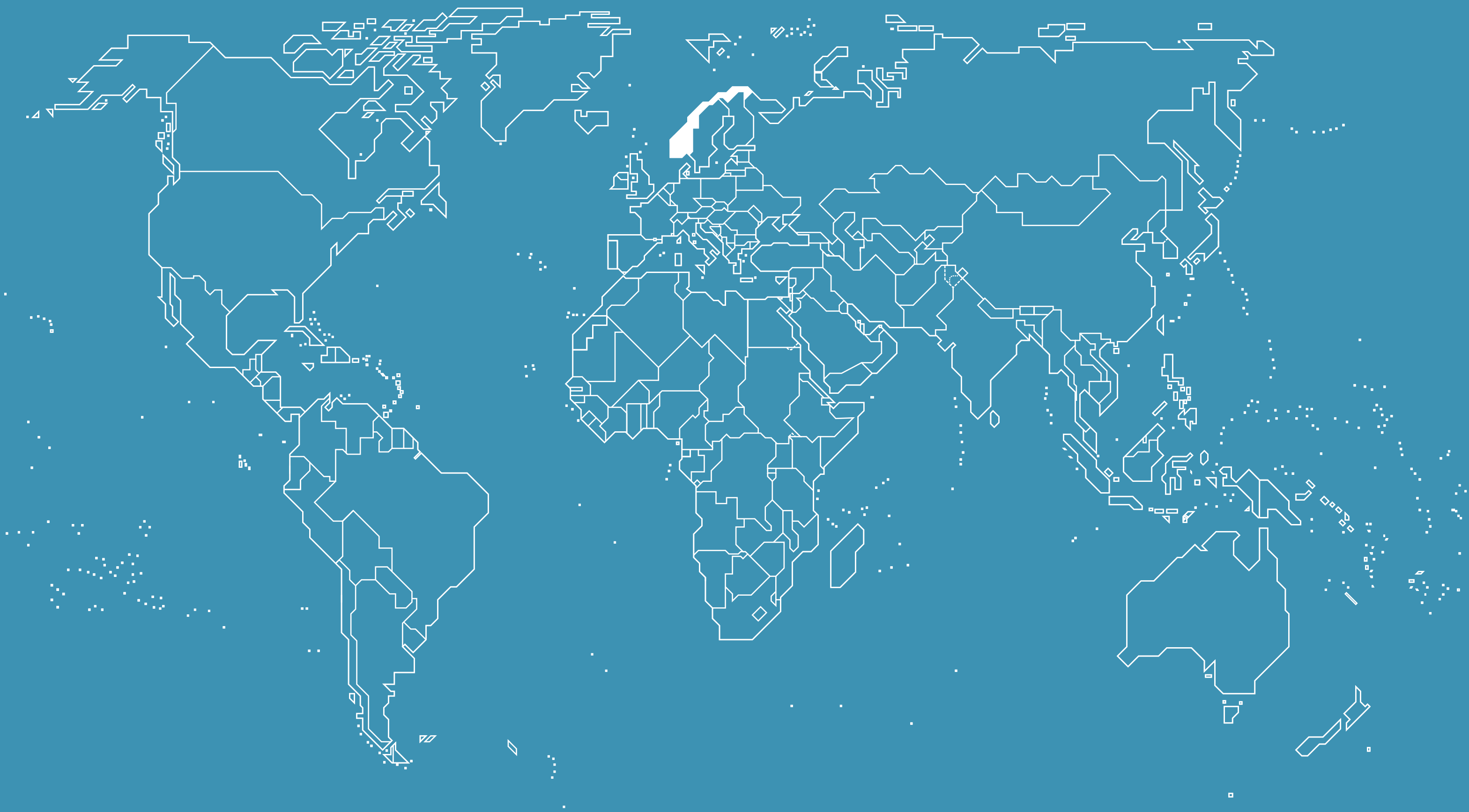

Norway

Author: Line Diana Blytt

Biosolids/sludge quality and utilisation in Norway

INTRODUCTION

More than 90 % of Norwegian sludge is used for land application as a soil amendment product; where one-third goes to parks, sports fields, roadsides, the top cover of landfills, and two-thirds goes to arable land within the agricultural sector. In order to achieve the high rate of land applied sludge, stringent standards have been set for the content of heavy metals and pathogens, and the control of the odour nuisance has been given high priority. In fact the Norwegian regulation concerning sludge is stricter than those of most of the countries in Europe.

BENCHMARK SLUDGE

The benchmark sludge is not allowed to be recycled on arable land (agriculture), due to its high content of zinc and lead. To fulfil Norwegian requirements, lead has to be below 80 and zinc below 800 mg/kg dw. Sludge has to be treated in order to be hygienized and stabilized before application on land as an organic fertilizer or a soil amendment product. Depending on the treatment method, the metal concentration may increase during storage or anaerobic digestion because of degradation of organic material. The typical value for Norwegian sludge (mechanical dewatered) ranges from 25 to 30% dm, and thermal dried sludge between 80-85% dm. There is a possibility that the benchmark sludge has to be deposited at landfills if the lead content in the sludge increases above 200 mg/kg dm after the stabilization process. Incineration plants in Norway are not designed to receive sludge and their capacity is not designed for sludge incineration. An incineration plant needs special approval to receive sludge.

Provided that the benchmark sludge fulfils the quality class III (table 1) and is stable, hygienic and dewatered, the sludge would be used on such green areas as golf courses, parks and roadsides. The sludge can be used directly on site, however this is not recommended. It is better used as an organic source for soil production for landscaping construction and top soil. The sludge could not be used in private gardens because of the high zinc and lead concentration. The benchmark sludge is not regarded as a soil amendment/fertilizer for food production areas or to private gardens. Soil blends with sludge is an increasing market in Norway. To be used on sports fields and in kindergartens, the sludge must be blended in a soil product. A blended soil cannot contain more than 30% sludge (based on volume). From a landscape gardener's point of view, not more than 10-15% of the total soil volume should be sludge, due to sludge's high nutrient content.

NORWEGIAN REQUIREMENTS

In last part of the nineties, the policy to recycle organic waste increased, along with requirements to remove organic waste from landfills, in order to reduce emission of methane and leachate. Several municipalities started to source separate kitchen waste for making compost. The ministries found it necessary to harmonize the parallel regulations for different types of recycled organic waste. In 2003 a new joint regulation was initiated covering all organic materials spread on land derived from, i.e., farm waste, food processing waste, organic household wastes, garden waste and sludge. It was also believed that to elevate and standardize waste such as sludge would stimulate the sludge treatment plants regarding quality control and, sludge would be more acknowledged in the market. *The administration of the new regulation, "Regulation on Fertilizers Materials of Organic Origin", is led by the Ministry of Agriculture and Food in cooperation with the Ministry of Environment and Ministry of Health*. The regulation sets the following major requirements for organically derived fertilizers in general, with a few special requirements for sludge:

- All producers have to implement a quality assurance system.
- Quality criteria of the products include standards for heavy metal content, pathogens, weeds and impurities, in addition to a more general requirement of product stability (linked to odour emissions). There is a requirement for taking reasonable actions to limit and prevent organic micro-pollutants that may cause harm to health or the environment.
- Requirements on product registration and labelling before placement on the market
- Special crop restrictions for sludge, including a prohibition on growing vegetables, potatoes, fruit and berries for three years, and on spreading sludge on grassland.
- Requirements for storage facilities before use. Cannot be spread on frozen soil – no later than November and not before 15. February. Sludge has to be mixed into the soil (ploughing) within 18 hours after application.
- Beside the limit values for heavy metals, the hygienic requirements are: no *Salmonella sp.* in 50 grams and no viable helminth ova. and less than 2,500 fecal coliforms per gram dry solids.

Table 1. Norwegian restrictions on heavy metals in sludge and in agricultural soil (upper 20 cm) receiving sludge

Quality classification	0	I	II	III	
Land use	All purposes, arable land, gardens and green areas (roadsides, parks)			only green areas	
Maximum application	Unlimited use. Only fertilizer requirements	40 ton dw/ha per 10 years	20 ton dw/ha per 10 years	5 cm per 10 year	Limit values for agricultural soils
	mg/ kg dm				
Cadmium (Cd)	0,4	0,8	2	5	1
Lead(Pb)	40	60	80	200	50
Mercury (Hg)	0,2	0,6	3	5	1
Nickel (Ni)	20	30	50	80	30
Zinc (Zn)	150	400	800	1500	150
Copper (Cu)	50	150	650	1000	50
Chrome (Cr)	50	60	100	150	100

PRACTICES IN NORWAY

Norway is a country with a long coastline and is dominated by forests and mountains. Arable land covers three percent and is mostly located near bigger cities and at the bottom of the valleys. Norway has 4.5 million inhabitants. Most of the sewage treatment plants were built after 1970. During the seventies and eighties there was a major increase in the number of plants, especially in the parts of the country with discharges to inland waters and narrow fjords. The sludge is produced in about 1,400 treatment plants, of which most are very small. The sludge from smaller plants is usually transported to larger treatment plants. In total, 62 treatment plants have registered their treated sludge to be regarded as a fertilizer product. Total production of sludge is in table 2.

Table 2. Norwegian sludge production and utilisation, data for 2006

Category	Sludge (ton)	Sludge dry matter (ton)
Total production	227 645	86 030
Total utilization	224 011	86 484
Agricultural	141 684	56 055
Green areas	30 009	10 198
Mixed soil products	27 990	13 178
Top layer on landfill	12 421	2 934
Land filled	6 844	2 957
Other	5064	1162

In the mid-seventies, a reform in the agricultural sector changed the agricultural production in the populated regions around Oslo (the capital) and Trondheim. The agricultural practice changed from dairy farms with grassland to the production of cereals (barley, wheat, rye and oats) and oil seeds. Single-crop farming depletes the organic material in soil. Changes in the farm structure and land use are a contributing factor to the use of sludge on agricultural land. Sludge is not used in forests in Norway.

A farmer has to make a plan for all fertilizers to be spread on his fields, including sludge. The municipality has to be notified of sludge use at least tree weeks before it is locally stored or spread. The wastewater treatment plant or the sludge transport company often helps the farmer with this notification. A farmer cannot apply sludge more frequently than every 10 years on the same field, but that will depend on to the sludge quantity and amount he uses.

Applying sludge on arable land is considered by the norwegian authorities to be the socio-economically acceptable and cost effective way to utilise the sludge, however this implies that the farmer accept the use of sludge. the sludge market is sensitive to negative reports because farmers' acceptance is influenced by many factors. Farmers also need to consider the opinions of retailers and consumers. Authorities and waste water treatment plants continuously work on risk communication. This helps to sort the real facts from the false and provides balanced information to the partners. Markets within the landscaping sector are increasing. New markets for green energy may enhance cultivation for energy crops. This may increase sludge application on these types of arable land. There are ongoing experiments and pilots making synthetic diesel from sludge and organic waste. It is becoming more common to co-digest sludge and food waste in order to increase the production of biogas (methane). This will lead to a sludge quality with lower metal content, but higher nutrient content, which may be more desirable for farmers from a fertilizer perspective.

TREATMENT METHODS

To obtain stabilized and hygienized sludge according to the Norwegian regulation, these methods are commonly used:

- Thermophilic aerobic digestion
- Thermophilic aerobic pre-treatment + mesophilic anaerobic digestion (dual digestion)
- Pre-pasteurisation + mesophilic anaerobic digestion
- Thermal hydrolysis + mesophilic anaerobic digestion
- Mesophilic anaerobic digestion + thermal drying
- Thermophilic anaerobic digestion
- Composting (windrow or in-vessel)
- Lime treatment (addition of quicklime to dewatered sludge)
- Long-term (min. 3 years) storage of dewatered sludge

The most stringent hygienic requirement for sludge is no viable helminth ova (parasite eggs). The hygienization process needs to be designed according to this requirement. Typical treatment methods have been validated against their ability to deactivate *Ascaris* eggs and process recommendations have been given, see table 3.

Table 3. Critical limits for deactivation of Ascaris eggs based upon validation tests of different sludge hygienization processes

Hygienization process	Critical Limits (CL's) Minimum temperature (°C)	Critical Limits (CL's) Minimum exposure time (min.)	Recommended operating values
Pre-pasteurisation	65	30	70°C for 30 min.
Thermophilic aerobic pre-treatment	60	60	60°C for 90 min.
Thermophilic anaerobic digestion (semi-continuous, draw-and-fill mode)	55	90	55°C for 120 min.
Lime conditioning + vacuum drying	80	50	80°C for 90 min.
Lime treatment (quicklime addition to dewatered sludge)	55	120	55°C for 120 min.

ECONOMIC INFORMATION

Typical costs of operation are as follows:

- Typical proportion of sewage treatment costs are up to 50%, which includes both capital cost and operational cost;
- Typical charge to consumers for transport and treatment of 1 m^3 sewage is 16 NOK;
- One litre of diesel fuel costs about 12.58 NOK;
- 1kWh of electricity costs about 0.40 NOK.

DEWATERING

Mechanical dewatering is required to facilitate a successful operation. Sludge is dewatered by centrifuge or filter belt pressed and some sludge is dried thermally. Besides, application of liquid sludge is atypical in Norway, due to long transport distances, need of storage 4-5 months before spreading, risk for odour and runoff. Conditioning of sludge before mechanical dewatering is done by different techniques, addition of polymer (most common) or lime.

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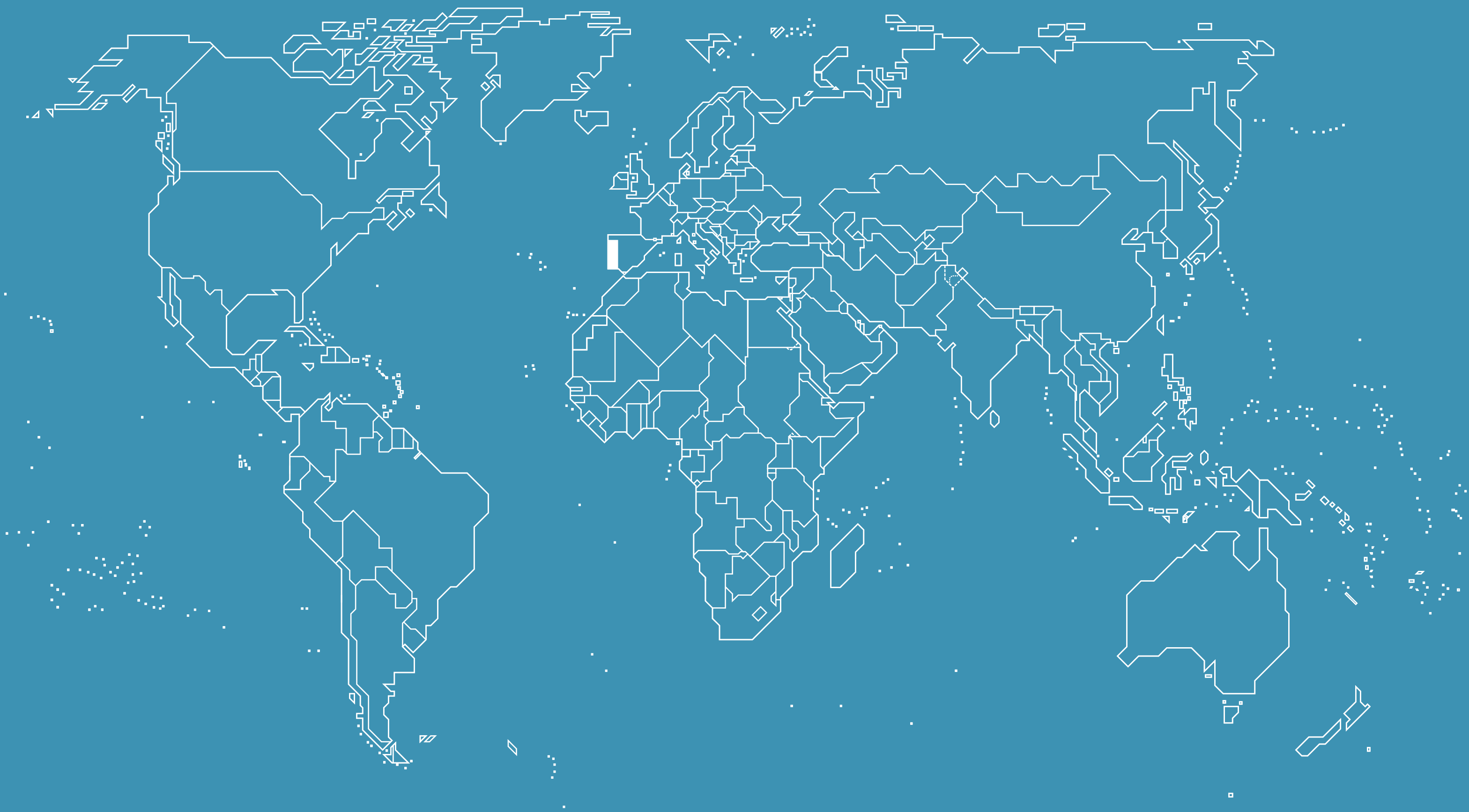

Portugal

Author: Elizabeth Duarte

Portugal

INTRODUCTION

The situation concerning sludge treatment and disposal differs, as population density and percentage of inhabitants connected to a wastewater treatment facility varies widely.

Therefore, regional sludge production depends not only on the number of inhabitants, but on the development of wastewater treatment as well. The combinations of both factors results in different solutions for sludge management.

In the last four years there was a major effort in the requalification of existing Waste Water Treatment Plants (WWTP) and construction of new ones, leading to a growth on sludge production.

Until recent years, the most common use for sludge from WWTP was landfill disposal. Nonetheless, this disposal system is becoming more and more restricted as, on one hand, regulations regarding the disposal of organic matter become more limitating and, on the other hand, the cost of this land disposal is rising. In addition, incineration is seen by public opinion as unwelcome, and increased protest actions appear every time a waste incineration plant project is presented.

As such, agricultural use of sludge appears as the process with a faster growth in Portugal, representing, at the present time, the preferred method of sludge disposal. With the development of the waste water treatment systems, more and more operators have appeared to perform the transport and application of sludges in agricultural and forest land. However, at the same time, a group of other industries and activities has been electing agricultural land for the disposal of its waste and undesirable by-products. As a result of this competition, more and more agricultural areas are required to absorb the production of sludge from agro-industries, municipal solid waste (MSW), manure and slurry from intensive livestock production.

Meanwhile, consumers and public opinion are increasingly demanding more quality in agricultural products. In return, certification systems are more exigent and agricultural producers as well as other enterprises along the food chain are becoming more accountable for the quality of the products, they deliver to the market. The Common Agricultural Policy (CAP) itself presents a set of standards regarding agricultural practices regarding environment conservation and quality standards for agricultural products.

PORTUGAL SLUDGE PRODUCTION STATE OF ART

Portugal (mainland) is a country with about 10,110,000 (2006) residents distributed by 28 NUTS III (Nomenclature of Territorial Units for Statistics III), which can be grouped by 5

CCDR (Commission of Regional Coordination and Development), namely, Algarve (422,000 residents), Alentejo (764,000 residents), Lisboa e Vale do Tejo (2,794,000 residents), Centro (2,386,000 residents) and Norte (3,744,000 residents).

Nevertheless, only about 78% of the Portuguese population (7,886,000), on average, is served by a municipal sanitation system, from which about 83% are directed to Waste Water Treatment Plants (WWTP), i.e. 65% of the nationwide population is served by WWTP (6,572,000). The Southern regions (Algarve Alentejo and Lisboa e Vale do Tejo) have about 76% of residents served and the Northern regions (Centro and Norte) about 58%.

In Portugal the WWTP and sludge management is carried out mainly by multi-municipal systems, covering about 80% of served population and the remaining 20% by municipalities and private sector.

Regarding the type of wastewater treatment that originates the sludge, Table 1 summarizes the population served and number of WWTP distribution.

Table 1. Population served and number of WWTP distribution

	Served Population		WWTP	
Treatment type	**Amount**	**%**	**Number**	**%**
Preliminary treatment	624,300	9.5	4	0.1
Primary Treatment	617,800	9.4	42	1.1
On Site Sanitation Systems	479,700	7.3	2,645	69.7
Secondary treatment	2,799,700	42.6	850	22.4
Tertiary treatment	1,577,300	24.0	57	1.5
Undefined	473,200	7.2	197	5.2
TOTAL	6,572,000	100.0	3,795	100.0

Although only about 65% of the Portuguese population is served by WWTP we have to consider that, besides the domestic effluent, there is also industrial effluent that is conducted to these WWTP, increasing, on average, 50% in the Southern regions and 70% in the Northern regions, where industry represents a greater weight. Considering these two incoming flows in the WWTP, it is possible to estimate, with some degree of accuracy the population equivalent (p.e.) served by the WWTP in Portugal for each region (Table 2).

Table 2. Population equivalent (p.e.) served by the WWTP in Portugal for each region

Region	Served population	p.e. ponderation (%)	p.e.
Norte	2,059,000	70	3,500,300
Centro	1,503,000	60	2,404,800
Lisboa e Vale do Tejo	2,151,000	60	3,441,600
Alentejo	535,000	50	802,500
Algarve	333,000	50	499,500
TOTAL	6,572,000	62	10,648,700

Regarding the sludge production, the available information is scarce and dispersed. However, two major field studies have been carried out regarding the sludge management from WWTP in two different Portuguese regions: Algarve (2005) and Center Alentejo (2006). These studies allowed us to evaluate, with some accuracy, the amount of sludge produced, as well as its classification by type of treatment.

Table 3 summarizes the estimated sludge production (dry matter) by p.e. per day and region.

Table 3. Estimated sludge production (dry matter) by p.e. per day and region

Region	p.e.	Sludge range (g DM/pe.day)	Sludge prodution (ton/year)
Norte	3,500,300	80	102,209
Centro	2,404,800	50	43,888
Lisboa e Vale do Tejo	3,441,600	50	62,809
Alentejo	802,500	70	20,504
Algarve	499,500	40	7,293
TOTAL	10,648,700	60	236,703

The range assumed for the sludge range (40 – 80 g DM/pe.day) depends, mainly, on the sludge treatment process, i.e., if the sludge is digested and if lime is added (upper limit for non-digested sludge with lime addition and lower limit for digested sludge without lime addition).

PORTUGAL ECONOMIC INFORMATION

- Cost of diesel fuel: 1,234 € / Liter;
- Energy cost: 0,0540 € – 0,0988 € depending on time of day.

PORTUGUESE SOILS AND SLUDGE AS A SOIL IMPROVER

The mild and dry climate in Portugal favours a fast mineralisation of the organic matter. This fact, together with agricultural practices and the soil type leads to reduced values of organic matter in most of the agricultural land. These low levels are an important constraint to the development of most agricultural crops, thus representing a limitation to the growth of the agriculture production, in Portugal. One can observe this especially in the Centre and Southern regions of the country, whereas in the Northern region the climate and soil types are less favourable to the organic matter mineralisation. Moreover, intensive livestock production, in the latter region, has been providing the manure application in these soils.

Most of the soil in Portugal is acidic (172 thousand hectares with a soil pH under 4.5 and 3,000 thousand hectares with a soil pH between 4.6 and 5.5).

Alkaline soils exist in few areas such as the limestone area of the Serra dos Candeeiros (in the Central region); the Serra Algarvia (Southern region) and some small areas in Alentejo, according with the acidity and alkalinity soil map (see map).

Sludge from WWTP, when blended with lime, acts as an alkaline soil conditioner. Thus, it is indicated for acid soils, where its application in appropriate quantities can contribute significantly to raise its pH to more favourable levels for agricultural crops. As a consequence, yields are increased. On the other hand, when the sludge stabilisation is accomplished by other means, acidification action of the soil may occur due to the mineralisation of the organic nitrogen and sulphur into nitrate and sulphate through microbiological processes that lead to acidification. Nevertheless, this acidification is never as pronounced as that spurred by some nitrogenous fertilisers commonly used.

Alkaline soils will benefit from the acidifying effect of these sludges, nonetheless the continuous application in acid soils will increase its acidity hence the necessity of manuring the soil by lime.

One can conclude that the application of sludge in agricultural soils can represent an important improving factor of its physical characteristics (increases drainage capacity, water retention, thus reducing the soil erosion risk); and chemical characteristics (increases the nutrient retention and the activity of micro-organisms). Nevertheless, a few dangers and annoyances are associated with the unregulated application of sludge.

SLUDGE RECYCLING IN AGRICULTURE: APPLICATION AND LIMITATIONS

According to Decree-law 118/2006 (published on June, 21, 2006), sludge application in agriculture is restricted to:

- grassland and forage crops, when grazing animals or harvesting forage in less than three weeks;
- fruit and vegetable crops, during their growing season (excluding fruit trees);
- fruit and vegetable crops in direct contact with the soil and normally eaten raw, during a ten month period before harvest;
- soils under organic farming.

The main agricultural crop receiving sludge is maize, followed by vineyards and orchards. Some sporadic applications occur in forage areas and in foresting actions after forest fires.

The most common application method of sludge in agriculture is to add it to the soil. Sludge is first distributed over the soil and then ploughed down or deep-injected into the soil. According to the legislation in force, the latter operations have to occur in the two days after its distribution. This generally takes place after harvest and before planting in the following season. However, in large areas it is commonly pointed out by operators that the legislation in force is poorly adapted to the reality: bureaucracy associated with sludge disposal and inadequate and impracticable controls.

As a consequence, operators are considering an alternative option for sludge disposal to agriculture recycling: its destruction by incineration. At the same time a revision of the decree-law is on-going.

Concerning the soil chemical composition, some limitations exist regarding the heavy metal content (Table 4) and the maximum amount of sludge to be applied in each ten-year period (Table 5).

Table 4. Maximum heavy metal load allowed in the soil (mg/mg DM)

	pH value		
Parameter	**pH <5,5**	**5,5<pH<7,7**	**pH >7**
Cadmium	1	3	4
Copper	50	100	200
Nickel	30	75	110
Lead	50	300	450
Zinc	150	300	450
Mercury	1	1.5	2
Chrome	50	200	300

Source: DL 118/2006

Table 5. Maximum heavy metal load to apply under agricultural land (kg/ha/year), based in a ten-year average

Parameter	**Maximum load (kg/ha/year)**
Cadmium	0.15
Copper	12
Nickel	3
Lead	15
Zinc	30
Mercury	0.1
Chrome	4.5

Source: DL 118/2006

PERSPECTIVES OF EVOLUTION OF THE SLUDGE RECYCLING IN PORTUGAL

Recently published studies point to the Northern and Central WWTP as those with more difficulty in disposing sludge for three main reasons:

- firstly, as these are more populated areas, the WWTP produce more sludge;
- secondly, because the available agricultural area is reduced;
- and finally, in these areas intensive livestock production occurs, with the correspondent manure and slurry by-products.

In fact, sludge movement between regions is already noticeable between the regions of greater sludge production and those where larger agricultural areas are available, making possible the agricultural recycling of sludge. It is expectable that, in the medium term, these movements are intensified, implying increased management and transport costs.

However the perspectives for the agriculture development do not support an indefinite increased sludge recycling by agriculture:

- on the one hand, a continuous reduction of the cultivated area is happening, with wider areas devoted to forest or fallow land;

- on the other hand, consumers demand more quality controls on agricultural products, creating in agricultural producers less receptivity to sludge application[1], as long as WWTP do not guarantee the quality of the sludge.

Despite the growing sludge production and its potential benefits for the agricultural soils in Portugal, producers have reduced capacity to recycle them in agricultural soils. Thus they will elect other fertilisers and ameliorators.

Taking this into consideration, improvement of the sludge quality in terms of safety (heavy metals), hygiene and application is essential in order to fulfil completely the legal requirements and to provide a trustworthy source of organic matter to agricultural and forest soils.

Regarding the future perspectives for the Portuguese agriculture that may increase the interest in sludge recycling, one has to mention the development (on-going) of irrigated areas namely in the Alqueva watershed, as well as increasing areas devoted to energy crops for biomass, in marginal areas.

To conclude, one can state that recycling sludge by agriculture in Portugal it is *possible* and *desirable* (improves soils and agriculture fertility). Nonetheless, its treatment and production will have to be more *controlled* in order to achieve sludge capable to assure *quality* and *safety* to agriculture producers.

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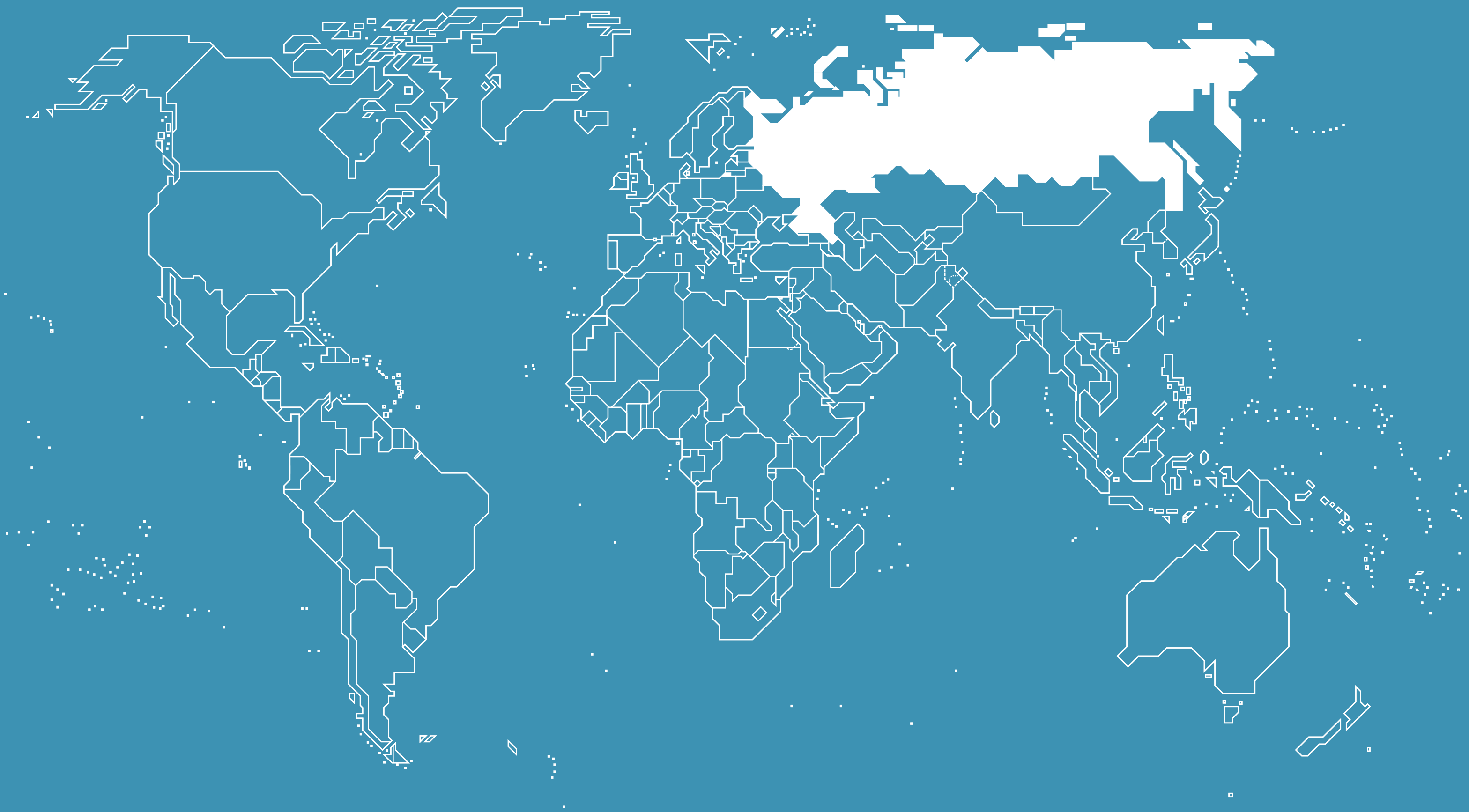
Decisão de Conselho 2003/33/CE de 19 de Dezembro de 2002.

1 *In past years, some agricultural producers applied sludge non-treated, without knowing it. This was detected in controls and caused prejudice for the agriculture and for consumers.*



Russia

Authors: L. Gunter and S. Belyaeva

Russia

BACKGROUND

A total area of Russian Federation (RF) is more than 17mln.km^2 and the population is more 140 million residents. RF includes 83 regions and more 1000 towns. The population of 25 towns is more 500,000 residents.

The total capacity of wastewater is about 55 million m^3 per day.

About 15% of all wastewater is untreated. The wastewater treatment plants have a capacity of 3000 to 2.5 million m^3 per day. Small villages, sanatoriums, campings have treatment plants of less than 3000 m^3 per day.

RF annually forms over 80 mln, m^3 per year of sludge.

In the course of almost 50 years of use of biological purification of wastewater, there has been a development of techniques and hardware for the treatment of sludge, with the objective of maximal reduction both of volumes and land areas for sludge beds, which are still used for sludge decantation at many treatment facilities.

At present, for big WWTPs, a decrease in volumes of sludge is attained by using approved modern technologies:

- Thickening
- Stabilization
  - thermophilic or mesophilic anaerobic digestion
  - aerobic stabilization (digestion)
  - lime stabilization
  - or not stabilization
- Dewatering by employing
  - filter presses (conditioning with polyelectrolytes)
  - belt filter presses and centrifuges. (conditioning with polyelectrolytes)
- Pathogenie decontamination
  - Thermophilic anaerobic digestion
  - composting
  - addition of lime
  - drying on sludge beds

In 1998 the Federal Law of the Russian Federation (of 24.06.1998 r. no.89- FZ) "On Industrial and Consumption Waste" fixed the legal bases of regulation of the environmentally safe treatment and disposal of waste. This Law determines the following main principles of the state policy in the field of treatment of all kinds of wastes:

- maximal reduction of their volumes;
- preparation for their further safe recovery;
- temporary storage or burying, environmentally safe for the population's health and for settlement places;
- elaboration of standards, regulations, rules, etc.;
- certification of certain types of technological processes, equipment, products (including the waste itself), works that may represent a potential threat to humans and to the environment;
- obtaining licenses for certain kinds of activities connected with toxic waste.

At present, the Provisions and Orders of the Ministry of Natural Resources have formed a system of bylaws regulating the order of execution of principal requirements of the above-mentioned Federal Law for all kinds of wastes, including the wastewater sludge.

The most important of these acts are as follows:

- On the rules of elaboration and adoption of the norms for formation of waste and of the limits for its placement;
- On adoption of the Federal Classification Catalog of Waste;
- Criteria for classification of waste according to its danger for the natural environment;
- On adoption of the passport for dangerous waste;
- Provision on licensing the activities for dangerous waste treatment;
- On norms for payment for placement of industrial and consumption waste, et al.

SELECTION OF DISPOSAL PRACTICE

The method of selection of suitable use or disposal option by sewage treatment operators depends on the local situation and economic considerations, the composition and properties of the placed sludge.

In the practice of the Russian Federation, the following principal methods of the sludge final disposal have been approved:

- land application, including recovery as fertilizers for various kinds of agricultural, technical, forestry, flower and other cultures, urban landscaping
- storage or burying on sludge bed, on special grounds and co-disposal at municipal landfill (landfill option)
- use for rehabilitation of damaged lands and of the same above-mentioned grounds.
- incineration option.

As demonstrated by the experience of the RF, it is impossible to solve unequivocally the problem of the final disposal of sludge at treatment facilities of various capacity in the regions with different climatic conditions, land resources, necessities in fertilizers for agriculture, forest restoration, facilities for growing forest and decorative trees and bushes, availability of necessary territories for the grounds for storage and burying of wastewater sludge, cost of land, distance to the area of the wastewater sludge placement and the relevant transport charges and other features.

Each of the above-stated placement methods, including the incineration, influence the soils, underground and superficial water sources and atmosphere in a different way, which is connected with the placement technique itself, the composition and properties of the placed sludge. The latter are just the main criteria for selection of an environmentally safe method of placement, the requirements that are at the basis of normative documents used in any country.

Modern approach to disposal of wastewater sludge is impossible without such procedures as certification – an independent and qualified evaluation whether the formed sludge corresponds to the regulatory documents. RF-developed ecological certification trials, having been carried out for many years, allowed the formation of a data bank on composition and properties of sludge, which were accumulated and formed at WWTPs in cities and villages.

Table 1. Heavy metals of sludge form annually in the Moscow region

Metal	Concentration (mg/kg)
Lead	0,8 – 1070
Cadmium	0,0 – 300
Nickel	1,4 – 306
Mercury	0,0 – 11,35
Copper	0,9 – 1200,0
Zinc	3,0 – 3820,0
Chromium	18,2 – 1280,0
Arsenic	0,0 – 24,0

ECONOMIC INFORMATION

The costs of the sludge operation are as follows.

- Typical proportion of sewage operation costs attributable to sludge: 25% capital, 22% running cost.
- Charge to customers of 1m³ sewage: 8-12 rubles/m³*
- 100litres of diesel fuel about: 19 rubles at public pumps
- 1kw h of electricity about: 2,8 rubles.

*The current rate is about 23,8 rubles to $1 in March 2008.

USE AS FERTILIZERS

The principal norms in force in the Russian Federation, determining the requirements of the composition and properties of sludge when recovered as a fertilizer, are the following:

- Union State Standard (GOST R) 17.4.3.07-2001 "Protection of Nature. Requirements to the wastewater sludge properties when used as fertilizers";
- Sanitary rules and norms 2.1.7.573-96 "Requirements of the wastewater and to its sludge when used as fertilizers";
- Typical technological schedule for use of the wastewater sludge as organic fertilizer, 2000.

The above-mentioned documents regulate: 1.The agro-chemical parameters (content of nitrogen, phosphorus, pH), 2.Concentrations of heavy metals (Table 2), 3.Sanitary and hygienic parameters (bacteria of colibacillus group, pathogenic microorganisms, helminth eggs), moisture and content of organic substances. If the first two groups of parameters mainly depend on the wastewater composition, the rest depend on the technological schedule and equipment for sludge treatment applied, which should provide for the fulfillment of the norms in force. The normative parameters of the sludge quality for different methods of its final placement have been determined considering the requirements of the EC Directives and of the norms in force in separate countries.

Table 2. Maximum permissible concentration of heavy metal of sludge (mg/kg)

Metal	1st. group of sludge	2nd. group of sludge
Lead	250	500
Cadmium	15	30
Nickel	200	400
Mercury	500	1000
Copper	1750	3500
Zinc	750	1500
Chromium	7,5	15
Arsenic	10	20

1st. group of sludge – all agriculture except mushrooms, strawberries, green vegetables.

2nd. group of sludge – technical, forestry, flower and other cultures; urban landscaping, storage and burying and special grounds and grounds for solid sanitary waste; use for rehabilitation of damaged lands and of the same above-mentioned grounds.

Certification tests of sludge of WWTP more 150 states RF showed, that:

- sludge treated by old technology and having stayed for 5 years at drying beds had high mineralization and an increased content of some heavy metals. These results were used as a basis for spreading these sludges on specially organized solid waste drying grounds
- at the same time, properties of freshly dewatered sludge complied with requirements of the GOST R 17.4.3.07-2001 for heavy metals and may be used as fertilizes.
- some sludge could contain heavy metals in concentrations close to, or exceeding, the standard values. Among such metals are cadmium, zinc and chrome.

- moreover it has been determined that there was a tendency towards reduction of heavy metals concentrations in the sludge. This fact is connected with local treatment of the industrial sewage water.
- in the sludge of many WWT plants, concentrations of heavy metals are lower than maximum allowable concentration of soil (Tabl.3).

Table 3. Maximum permissible concentration of heavy metal of soil (mg/kg)

Type of soil	Pb	Cd	Ni	Hg	Cu	Zn	As	Cr
Sand soil	32	0,5	20		33	55	2,0	
Clay soil Ph < 5,5	65	1,0	40	2,1	66	110	5,0	90
Clay soil Ph > 5,5	130	2,0	80		132	220	10	

In sludge of the WWTP of the Moscow region, in more than 70% of cases, the contents of nickel, mercury, and chrome are lower than maximum allowable concentration of soil. The contents of cadmium, copper, and zinc are lower than maximum allowable concentration of GOST 17.4.3.07-2001 (group 1). Thus, heavy metal contents at many plants do not appear to be the main reason for insufficient recycling of sludge. The main reason is non-market conditions and poor sanitary standards.

The characteristics of sludge can be significantly improved by means of composting with organics-containing fillers. Composting is considered to be an important phase of recycling strategy in RF, which makes better physico-mechanical, chemical and sludge sanitary standards. The sludge transforms from the "waste" category into the "product" category. As a result, the ecological hazard at treatment plants comes down.

FORESTRY

Disposal of the benchmark sludge as an organic fertilizer and soil support in forestry is the most favoured option. The benchmark sludge quality falls within the contaminant 2nd.group of sludge for nonagricultural applications and could be applied to plantation of deciduous and coniferous trees Sludge could be used after pathogen reduction, composting or in mixture with sand and peat. The typical application rate is 60-80 t DS/ha.

LANDFILL OPTION

At present in RF, the majority of sludge is disposed on sludge beds, on special landfill and as co-disposal on municipal landfill with domestic wastes.

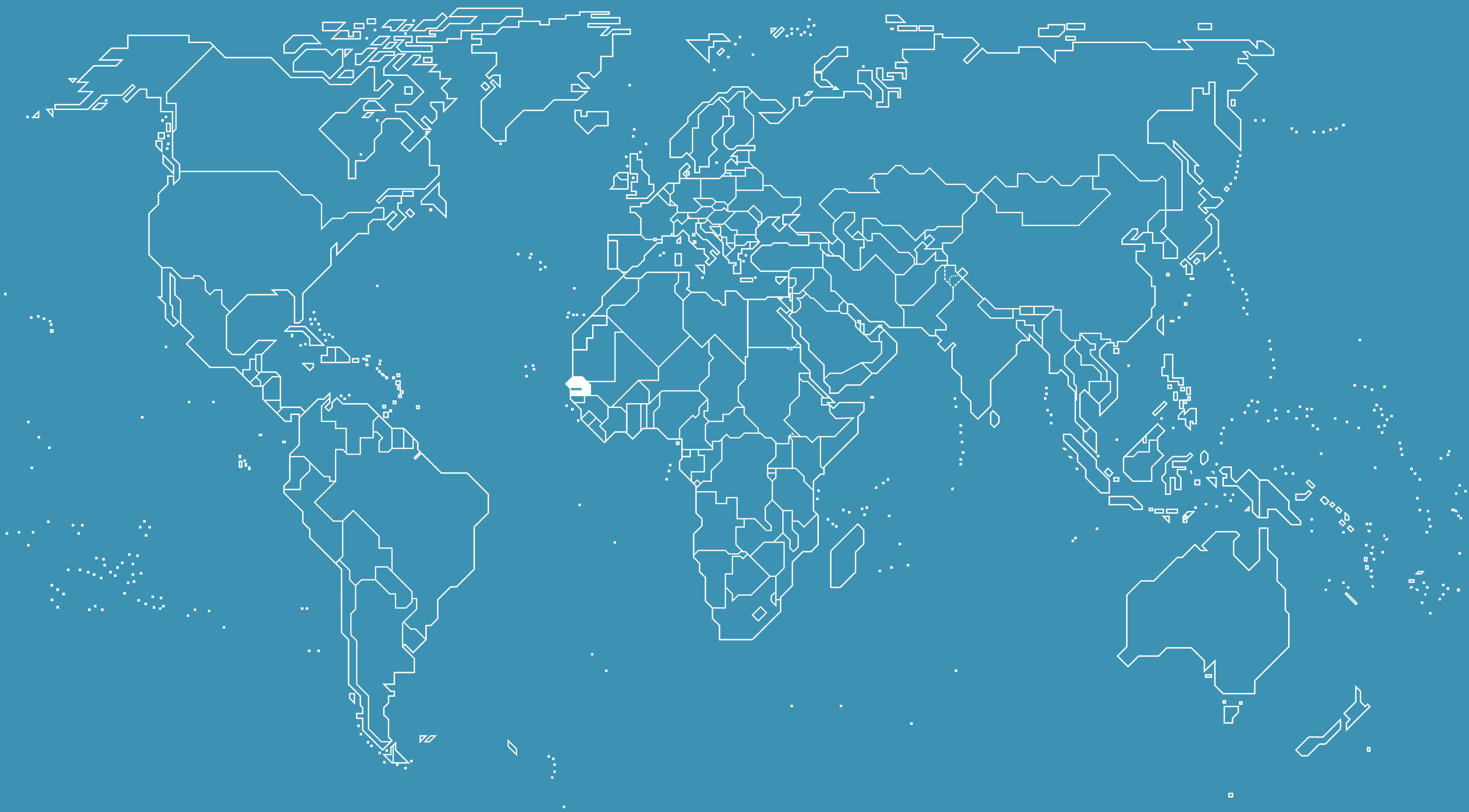
Regardless of its disadvantages, the method of natural decantation at sludge beds, if used at normal regimes, with timely elimination of the dried sludge, is applicable, in the first turn, for

WWTPs of low and medium capacity, as well as for the regions of sharp continental climate, where the separation of water from the solid fraction of sludge improves due to its winter freezing and subsequent defrosting, as well as to an intense heating in summer. Some methods of intensification of the sludge beds operation may improve the sludge decantation, including the following: — the preliminary conditioning of the sludge by organic flocculants before its transfer to sludge beds, which allows substantial reduction of the duration of decantation process and, therefore, the occupied land areas and improvement of the indicators of the dried sludge. An efficient protection of the sludge beds from atmospheric precipitation can be made by a transparent glass or film covering, which, in some cases, allows reduction of the area required for sludge drying by 33%. The closed beds are recommended for use in conditions of cold and damp climate, as well as in resort areas to save space and reduce odours.

Co-disposal at municipal landfill is an expensive solution utilizing sludge as cover material instead of traditional soil. This method requires a higher concentration of dewatered sludge (<65%), that cam to achieve in mixture with a peat or good dewatering of sludge.

INCINERATION OPTION

At present, there are two incineration plants for municipal sewage sludge in St. Petersburg. The raw sludge is incinerated without stabilization. The pretreatment of the sludge consists only of gravity thickeners and centrifuges for dewatering. The ash is put into special grounds. Further treatment of the ashes for hardening will be necessary in the future.



Senegal

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Senegal

List of Abbreviations

AEPA	*Adduction à l'eau potable et à l'Assainissement*
EVA II	*Eau pour les Villes Africaines phase II*
ESAMII	*Enquêtes sur les ménages*
FND	*Fonds Nordique de Développement*
BM	*Banque Mondiale*
BAD	*Banque Africaine de Développement*
DRSP	*Document de reduction de la pauvreté*
ONAS	*Office National de l'Assainissement du Sénégal*
O.M.D	*Objectif du Millénaire*
PEPAM	*Programme Eau porta et Assainissement du Millénaire*
PAQPUD	*Programme d'Amélioration de l'Assainissement dans les Quartiers Périurbains de Dakar*
PSE	*Projet Sectoriel Eau*
PLT	*Programme Eau à Long Terme*
PSD	*Programme support Division*
NPO	*National Project Officer*
UE	*Union Europeenne*

CONTEXT

The city of Dakar, capital of Senegal, knows an exponential demographic growth currently. Between 2005 and 2015, the urban population will grow from 4,20 to 5,32 million people, and from 547,600 to 695,400 households, with an average rate of growth on this period of 2,4%. This situation is accentuated in the sub urban zones, with a real impact on infrastructures in general and sanitation system in particular. Consequences are difficult access to drinking water, hygiene and health. Otherwise, the drainage and sanitation networks of the city of Dakar are decrepit enough; they were essentially constructed in the 1950s and, thus, are about 60 years old, although still functioning relatively well. The network is essentially composed of a collective system, semicollective and autonomous. The Government of Senegal took the option to inject consequent investments through the PEPAM with the support of international institutions (BM, FND, BAD, AFD, and UNO-HABITAT etc.) to increase the rate of access substantially to the level of Dakar, the Capital of Senegal and the other urban centres by 2015 in accordance with the objectives of the Millennium.

In such big cities as Dakar, Thiès, Kaolack, and St.-Louis, drainage of the muds or sludge collected from pits are carried usually out by trucks; that is not the case in secondary cities and the peripheral districts, where the sludge is disposed of more frequently manually and more often thrown into the environment, with a real risks of increasing environmental pollution.

OVERVIEW OF HOME SANITATION: ATTEMPT OF CLASSIFICATION

The infrastructures of collective sanitation

In 2003, 70.250 households were connected to the sewerage system in Dakar, representing approximately 25%. And the sewerage network in the administrative region of Dakar (Dakar, Pikine and Rufisque) is composed of 742 km and 43 pumping stations.

The big part of the used or waste water collected by the network is disposed of directly in the ocean without any treatment. In the other cities all waste waters collected are directed to a treatment plant, while in Dakar, 14% of the volume of the waste water is collected and treated. Dakar has two treatment plants.

- the station of Cambérène, using the activated carbon process,;
- the station of Rufisque: using the lagoon technique and completed in 2004.

A major problem of sewage system in the Town of Dakar is that it has been designed to collect waste water but presently the system also collects rainfall; so, during the rainy season, the system regularly overflows. The global situation of the sanitation system is as follow:

- 13% of households have access to the sewerage network;
- 14% of the waste water collected by the networks in the City of Dakar are treated at he station of Camberene;
- the 86% of the waste waters are disposed of into the sea (for Dakar), infiltrated into soil (Louga), disposed of into a river (Saly and Kaolack), or reused by the market gardeners (St.-Louis).

Infrastructures of autonomous sanitation systems

In the main and secondary cities, 90% of the households have an individual pit latrines system (traditional and modern type) only 34% have a system of evacuation of waste water. The 66% of the households remaining dispose of waste water in the in the immediate neighborhood (street, land, etc.).

For households connected to the sewerage system, the system of evacuation of waste water is similar to the one for feces On the other hand, for households having access to the autonomous sanitation system; the evacuation of the waste water is only possible by a system of cesspool or septic tank (or lost well).

The management and the maintenance of the works in autonomous sanitation system in Senegal consist of draining out the pits and removing the plugging of the cesspools. Up to now the maintenance of the individual sanitation works system remains to the private domain, although sometimes agents of the hygiene Ministry services perform visits to inspect the level of hygiene at the household level.

The problems encountered on the management of the individual sanitation works system is bound to their maintenance; draining pits constitutes a real problem of hygiene; and the sludge collected is more often disposed of into the environment, with a real risk of environmental pollution.

Populations covered by the existing sanitation systems

According to the ONAS, 70% of the households of Dakar use some individual systems of sanitation; the distribution of these works is :

- septic tanks: 68% of the works, 48% of the households;
- insulated pits: 25% of the works, 15% of the households;
- latrines: 7% of the works, 5% households.

How much of these materials are managed in urban areas each year

The production of sludge in the region of Dakar has been estimated in 2005 to be more than 170 000 m^3. The Government of Senegal, with the support of the World Bank, through the PSE and the PLT projects and PAQPUD, achieved three pilot stations to manage the sludge, for a cost of 0,91 million USD and a total capacity of 220 m^3 per day at the station of Camberene, in the Niayes area and Rufisque (region of Dakar). It is necessary to note that the three plants achieved already are all connected to treatment plan and bound to continue the started treatment.

An important program of realizations of sludge depositing work is in progress in other cities in Senegal, where the accent will be put on designing of effective systems of collection and treatment sludge production centred on the reuse process.

An important part of the sludge extracted of from domestic septic tanks is collected and transported by trucks to one of the three existing stations of Dakar or to be disposed of simply in the environment. On average the quantity of sludge extracted from the treatment plant of Camborne and reused is estimated around 3300 Tons per year; The sludge drained from the treatment of waters used at the station is subject of contracts with local enterprises, which resell it to farmers to be used as compost for public gardening and parklands in Dakar.

It is necessary to underline also that, in some peripheral districts of Dakar, the emptying process of pit is ensured manually by specialized people named "Baye pelle"; these men perform the manual draining of septic tanks. The sludge collected is put either in a dug hole or within the house or the street. This dangerous practice exposes the "Baye Pelle", the members of the concession and even around (if the hole is dug in the street) to risks of disease and illness. Besides this, this practice can contribute to the pollution of the water table, especially in the zones where it shallow.

A model of individual pit latrine in use in a suburb district of Dakar

The strategies of individual sanitation system developed by the population are not standardized. The following points summarize the ways and means that local population develops to manage their waste water.

- Piped waters are, in the majority of the cases, evacuated toward a septic tank or a pit latrine. A proportion of the population that disposes of it into the environment exists however;
- Waters from baths or showers, in most cases, are routed toward the septic tank which receives the piped water at the same time or are admitted directly in a well for infiltration. However, some houses pour their bath waters directly into the street;
- The kitchen and laundry waters are generally also poured directly into the street or in wild discharge areas. A small proportion of the population evacuates its kitchen and laundry waters into a lost well, via a washing device or work.

It is widely admitted that the disposal of the urban sewage into streets causes a real hygiene problem. The mixture of the waste water with the noncollected solids waste can be the origin of major annoyances for the populations (disease spreading, bad smell, development of flies, illnesses and diarrhoea, etc.).

Strategic selection of disposal practice

The Ministry in charge of Water and Sanitation

The Ministry, in charge of drinking water and sewage, is the higher authority that is in charge of the strategies setting, policies and reforms in water and sanitation. Since the recent reform, the water company has been split into two parts, each one having financial autonomy. The main objective is to make the sector "viable"; which means to be financially attractive by generating enough resources to support the operational costs. The state, represented by the Ministry, fully delegates power to the Société Nationale des Eaux du Sénégal (SONES), the Senegalese water utility, in the area of potable water to negotiate funds ad make adequate investment to satisfy the demand for potable water.

Sanitation Company (ONAS)

The Senegalese National Office of Sanitation was created by law in February 22nd 1996; ONAS is the national institution in charge of developing all the national sanitation systems; in this case, ONAS is the institution charged by law to take decisions on what to do with sludge in Senegal; ONAS manages the whole process and signs contracts with local companies to collect sludge produced by the only sewerage plant in Dakar.

Municipalities

Recently ONAS, with the support of the World Bank, has designed an important programme of individual pit latrines with the collaboration of Municipalities in the suburban of Dakar and surroundings. So Municipalities of Guédiawaye, Ngor, Ouakam, Malika etc have been covered with this individual pit latrines programme facilities; it is something like 60 000 latrines, which have been built up with a contribution of impacted municipalities, NGOs and local populations; this has been considered as very successful because it has improved the hygiene situation of a number of households.

DECISION MAKING

Involvement of risk assessment

The existing official documents insist on environmental impact assessment to realize any water and sanitation project; official references are mainly:

- The code of sanitation: this code has been recently prepared; it has to be adopted by the National Assembly
- the Water Code: it protects water from lake, rivers and lists sanctions to be carried out in case of pollution
- the Code of Environment: the main objective of the code in Senegal is to achieve a good management and protection of the environment to improve the quality of natural resources such as natural reserves and water resources, and to fight and mitigate pollution of different sources.
- The Hygiene code: this code looks after risks related to contamination mainly from water or food consumption; but at the same time, the hygiene code has set up strong dispositions to protect populations from the deteriorations of the environment and from sanitation.

All decisions on the use of sludge are governed by official documents mentioned above; and any project have to comply with all these codes, which explain clearly how sludge is to be disposed of without any harm; but real problems are encountered when it comes to enforcement and making people respect these laws and regulations.

By what are decision driven?

Decisions are driven by demand and availability of resources; currently a national strategy has been set up and validated through PEPAM; and the whole policy is designed to meet the MDGs Objectives.

Politics, government bodies, NGOs, Municipalities and associations are consulted and their views taken into consideration during the validation process of the different water and sanitation strategies and documents

Who makes decisions?

- Final decisions on prioritization are taken by the Governments for big projects like sewerage systems, including sewage plants buildings. The total investments are provided by the Governments themselves through donors or resources provided by international financial institutions (WB, ADB, EU etc.)
- At a local level, Municipalities are given power to negotiate funds to realize projects related to the improvement of the sanitation of their own populations. UNHABITAT is now supporting communes like Ngor, Ouakam and Yoff to make an extension of a sanitation programme realized by ONAS with a financial contribution of the World Bank.
- During the realization of sanitation projects, local committees are implemented to involve and make populations participate in the management of assets. In the case of Ngor, Ouakam and Yoff, traditional and religious groups are members of the committees; and a strong participation of women is noticed.

ECONOMICS

Cost of disposal

The population benefiting from sewerage systems during 2004 to 2006 is estimated to have moved from 2004 to 2006 from 2 465 100 to 2 759 900 inhabitants (sewerage, l diameter sewerage and individual pits latrines). Volumes of domestic waste water produced in the town of Dakar has been estimated during 2006 in Dakar at 53 492 000 m^3 and that collected is 45 765 000m^3 At the Camberene Treatment plant, the treated volumes is estimated at 3 504 000 m^3 (i.e. 9600m^3/day representing 19%;

The average cost of cubic metre treated – paid from 127 to 186FCFA. The cost of electricity varies from 75 to 110FCFA per KWH. The cost of 1000 litres of diesel fuel has moved in average from 330 000 in 2000 to 550 000 FCFA.

The average cost of connection to the sewerage system has been reduced drastically and linked to the type of the cost and the type of building to be connected; the Government accepted to contract a loan to subsidize the contributions of the population to the cost of connections; so the cost has been switched from 250 000 FCFA to 15 000 CFA.

Conclusions on costs

At the Camberene Waste Water treatment plant, ONAS is experimenting with the reuse of sludge. The sludge is dewatered and transformed into compost, ready to be used as fertilizer for public gardens. Contracts have been signed with local companies, which retail them to flower producers.

PROCESSES OF TREATMENT, USE, AND/OR DISPOSAL

At the treatment plant of Camberene, two processing lines are now performing quite efficiently. The wastewater line arriving at the station goes through the following procedure: screening, washing and streaming; the sludge itself goes through digestion, dewatering, drying and composting.

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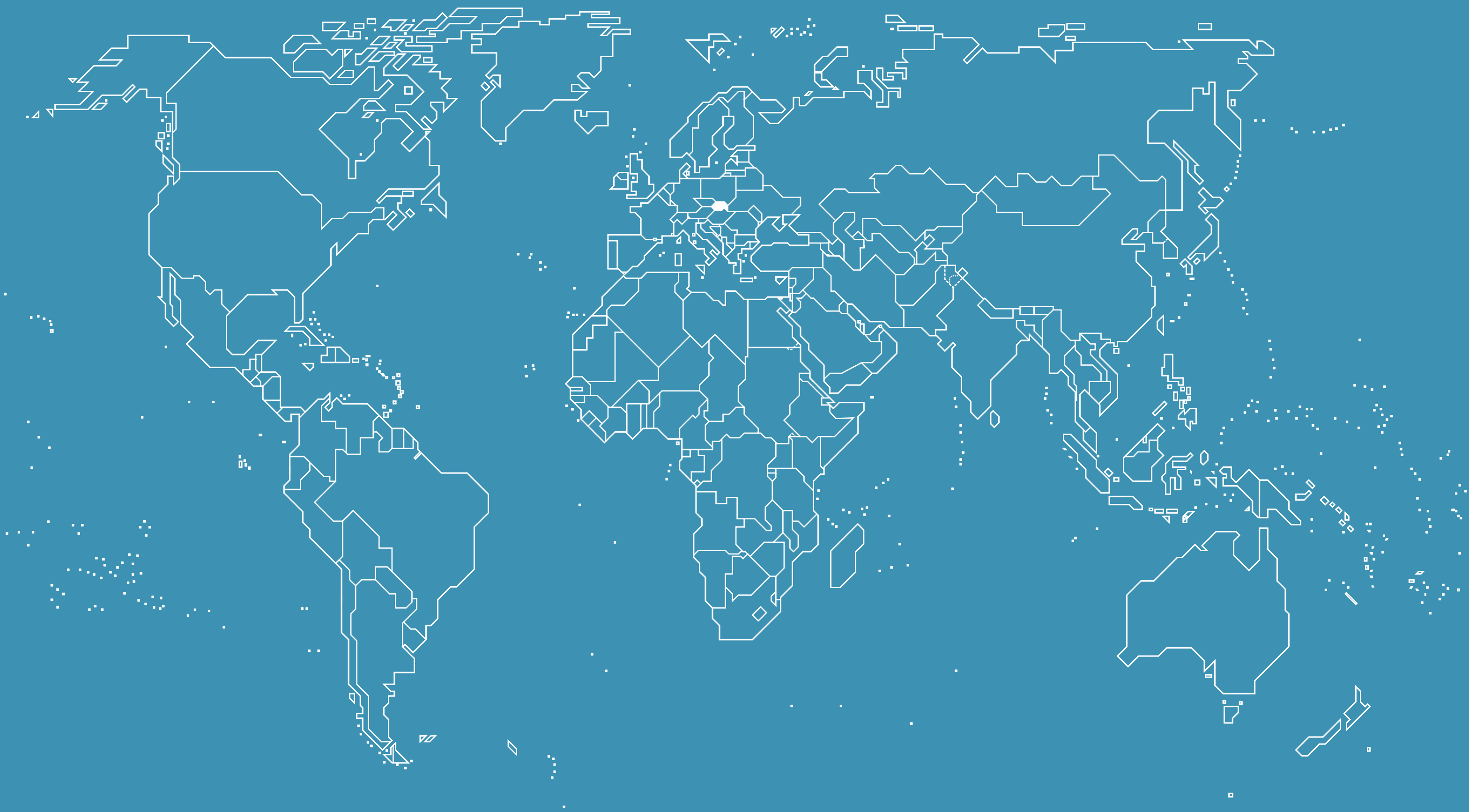


Slovakia

Author: Júlia Šumná

Slovakia

Sewage sludge (hereinafter "sludge") is waste, and sludge management in the Slovak Republic is generally regulated by the legislation valid for waste management respecting the requirements of acquis communautaire for this area.

Accordingly the waste holder is obliged to evaluate the waste resulting from his activities; to offer the unused sludge for recovery, to provide the waste disposal if the waste recovery is not possible or cannot effectively be done.

The amount of sludge generated in urban waste water treatment as well as the level of its contamination is permanently monitored and recorded.

Sludge protection against excessive contamination is placed in the legal regulations. Discharge of industrial waste water and special water containing dangerous substances into the public sewerage system is subject to decision procedure and one of the conditions for issuing the permission by the authority of the state water administration is that the sludge treatment and its further use will not be endangered.

Discharging the sludge into ground and surface water is forbidden in the Slovak Republic (Act on Waters no. 364/2004 Coll.).

CONDITIONS FOR SLUDGE TREATMENT

On the basis of the analysis of the conditions and development of sludge generation and the environs where this generation and the treatment process takes place, general principles of management conception of urban waste water treatment sludge were derived. Following the results of this analysis considering the hierarchy of principles of waste management according the European Union, the regulated sludge application into soil was created as the key mode of management of sludge from the Urban Waste Water Treatment Plants (WWTPs).

This process was selected not only as the relatively cheapest mode of final sludge management but for the Slovak conditions it is environmentally friendliest choice, fitting the requirements of sustainable development and observing defined regulations with systematic preparation and planning, monitoring and regulation of composition, sludge and soil properties (agronomic and environmental data), defined amount and plant production.

SLUDGE APPLICATION INTO AGRICULTURAL LAND

There are two techniques of regulated application into agricultural land:

1. Direct application of sludge into agricultural land according to the Act on Sewage Sludge Application into Agricultural Land, determining the conditions for sewage sludge application into agricultural and forest land without affecting soil properties, plants, water, health of humans and animals.

The implementation of the process described in details in the project of sludge application must be approved by the authority of agricultural land resources protection or, in case of application into forest soil (only soil in forest nurseries, in plantations with Christmas trees, fast-growing wood plants, energetic and intensive growths), by the authority of forest management state administration.

The act with certain hygienic and time limitations enables beside application into agricultural land application on permanent grass stands. It does not deal with the application into non-agricultural land or use of sludge in land reclamation.

Table 1. Limit values for heavy metal concentrations in sludge and limit values for amounts of heavy metals that may be added annually to agricultural land

Parameter	Concentration Limit Values mg/ kg DS	Maximal Amount g/ha/y
As	20	60
Cd	10	30
Cr	1000	3 000
Cu	1000	3 000
Hg	10	30
Ni	300	900
Pb	750	2 250
Zn	2500	7 500

2. Application in line with the Act on Fertilizers, for example compost, soil supporting substance or growing medium. In this case, the product made on the basis of sludge is subject to certification and assessment whether properties of such fertilizer and its technical documentation are in line with related technical standards and generally binding legal regulations.

INCINERATION OF SEWAGE SLUDGE

The possibility of using the sludge as the source of energy if its material recovery is not possible or practical is currently excluded in the territory of the Slovak Republic.

There are no suitable incineration capacities built for independent sludge incineration.

The capacity for waste co-incineration in two cement mills (others do not comply with the conditions of the Act on Air Protection) forms the significant part of the infrastructure of waste management of the Slovak Republic, but currently it is reserved for the handling with industrial combustible waste and co-incineration of animal waste. With regard to decreasing production of animal waste, the alternative sludge recovery can be considered in the future in these facilities.

The unfavourable situation in the area of energetic waste recovery is being solved. The Waste Management Programme in the Slovak Republic (WMP SR) for the years 2005 – 2010 has defined in this area the following objectives:

- to increase the energetic waste recovery to the level of 15 % out of the total waste generated in the Slovak Republic in 2010
- in 2010 to incinerate the waste only with energy recovery and related measures:
- combustible waste that cannot be materially recovered from economic point of view has to be turned into alternative fuel designed for co-incineration,
- to optimize the capacity of incineration facilities to the level of the needs of the Slovak Republic in line with the amount of waste for which the incineration is optimal way of recovery.

SLUDGE DISPOSAL BY LANDFILLING

Sludge disposal at landfill shall be the last choice of sludge management. In the Slovak Republic, however, it is the only way of sludge disposal with regard to insufficiency of combustion equipment.

Nowadays the shortage in capacities for this kind of waste disposal is not striking, and planned intentions to build landfills were to a great extent fulfilled according to the Waste Management Programme by the year 2005.

It is expected that the value of the organic part of waste disposed at landfills will be limited and directed to the support of processes power use or harvesting.

The aim of the Waste Management Programme of the Slovak Republic for this field is to decrease the amount of landfilled waste to 13 % out of the total amount of waste being generated in the SR by the year 2010, and among the measures to reach this it is requested to minimise the sewage sludge disposed of at landfills and increase payments for landfill waste services.

SLUDGE TREATMENT AND MANAGEMENT IN THE TERRITORY OF THE SLOVAK REPUBLIC

- Stabilization
  - Mesophilic anaerobic digestion
  - Simultaneous aerobic digestion
  - Separated aerobic digestion
  - Lime stabilization

- Dewatering
    - Filter press (conditioning with $FeCl_3$, lime or polyelectrolytes)
    - Belt press (conditioning polyelectrolytes)
    - Centrifuge (conditioning polyelectrolytes)

ECONOMIC INFORMATION

Proportion of sewage operation cost attributable to sludge 30-40% capital, 40-50% running costs.

- Charge to customers of treating 1 m^3 of sewage about EUR 1
- 100 litres of diesel fuel about EUR 120
- 1kWh of electricity about EUR 0.1

The following chart provides an overview of sewage sludge generation in operation of water companies and their way of management in the years 2005 – 2006.

Table 2. Annual quantities (t DS)

	Total	Incineration	Agriculture	Landfill	Forestry	Other
2004	53,114	0	41,116	10,581	0	1,417
2005	56,360	0	34,784	17,236	0	4,340
2006	54,780	0	33,630	15,375	0	5,775

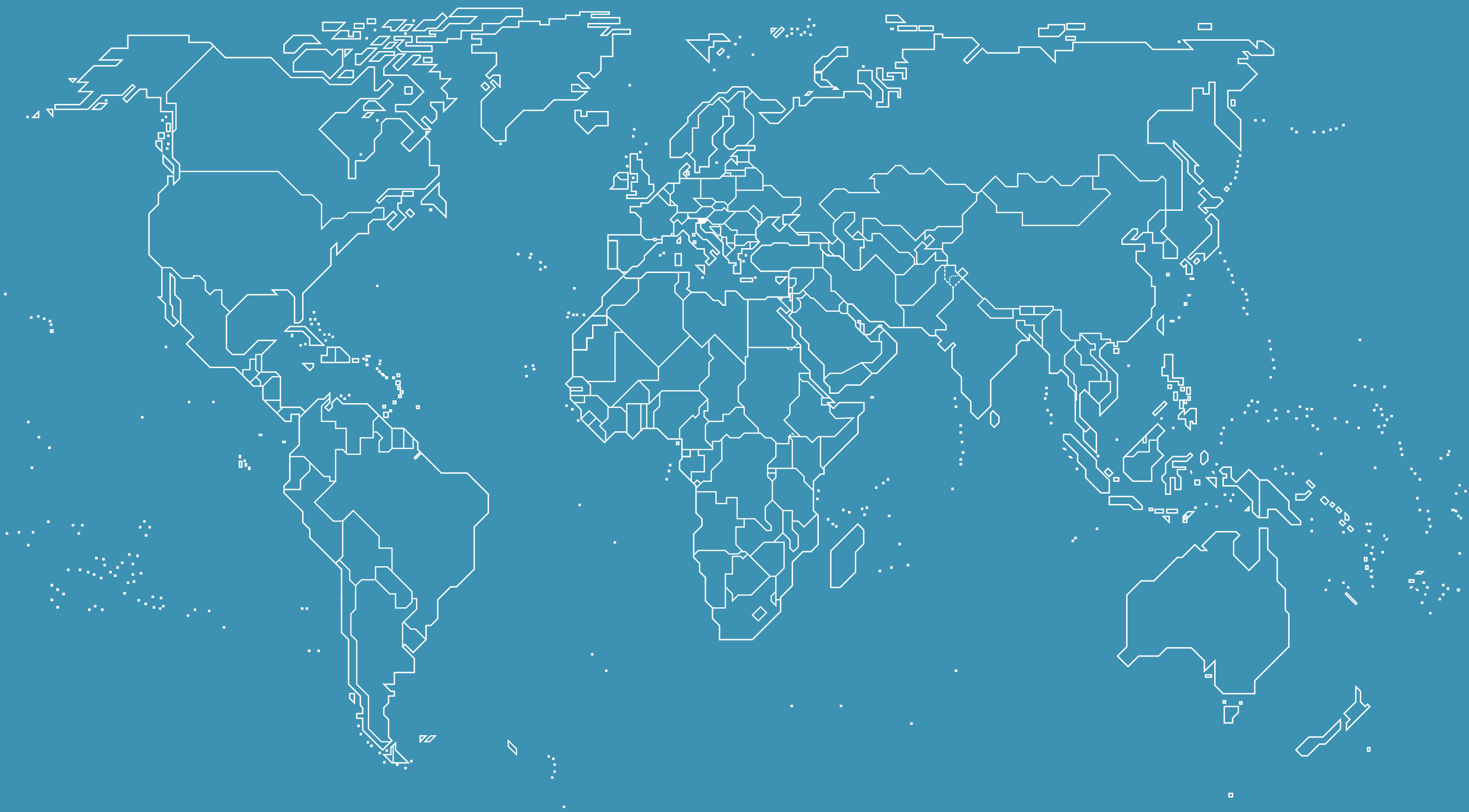
Note towards "Agriculture"
In 2004, 13 313 tons of dry solids (sludge) were directly applied into the agricultural soil; 28 803 tons of dry solids were used for the production of compost.
In 2005, 5 876 tons of dry solids were directly applied into the agricultural soil; 28 908 tons of dry solids were used for the production of compost.
In 2006, the sludge was not directly applied into the agricultural soil; 33 630 tons of dry solids were used for the production of compost.
The item "Landfill" also includes the rate of the sludge that was temporarily stored.

About 90 % of monitored sewage sludge production in the SR meets the limit values of risk substances concentration laid down by the law for process of sludge application into agricultural soil. Nowadays, by applying principle of consistent reduction in waste water contamination at inlet into WWTPs, the most serious problems with excessive sludge contamination related to industrial waste water discharging into public sewer system is considered as a solved issue in the Slovak Republic.

In regard to the increased requirements for waste water treatment – the Implementation Plan for Council Directive No. 91/271 of the European Communities on Urban Waste Water Treatment – it is necessary to count with an increase of sludge generation in appx. 20-40 %.

Considering the fact that the increase of sludge generation is mainly from small WWTPs, without important involvement of industrial waste waters, a certain degree of sludge contamination corresponding to requirements limiting application process into soil can be expected.

Nowadays within the sludge management the tendency is to further decrease sludge contamination, and this also from the perspective of organic contamination as well as increased level of hygienisation.



Slovenia

Authors: Viktor Grilc, Gregor D. Zupancic

Sewage sludge management in Slovenia

INTRODUCTION

Slovenia was a part of former Yugoslavia until 1991; in 2004 it became a new EU member state. It occupies 20.273 km^2 and has 2 million inhabitants. Its GNP is at present about 15.167 Euro/cap (2006). The state is organised into 193 municipalities of 2.500-250.000 inhabitants, spread on 5-500 km^2. Fresh water supply, wastewater treatment, sewage sludge disposal and solid waste are under responsibility of licensed public companies, located in the municipalities.

QUALITY REQUIREMENTS

The Environment Protection Act (1993, 2004) is the basic law that relates also to waste management. Subordinated is the Regulation on Waste Management, defining and regulating all waste types, prescribing also the reporting obligations. There are many complementary vertical regulations that relate to:

- most important waste management options (landfilling, composting, incineration…) and
- special types of waste (packaging, WEEE, old vehicles, spent oils, sewage sludge, construction/demolition waste, asbestos waste, battery waste etc.).

All the regulation has been transposed from international conventions and European directives.

Preparation of the noted legislation is under responsibility of the national Ministry of Environment. Implementation of the legislation is supported by several National Action Programmes. The executive responsibility has the national Agency for Environment, which:

- grants permissions, confirmations and authorisations to waste management companies,
- calculates (or exempts) taxes on waste generation
- maintains the national waste information database (lists of registered companies involved in waste management, waste management database).

Management of waste sewage sludge (and related wastes from municipal wastewater treatment) is regulated by several legislative acts, given by:

- The decree on the landfill of waste (OJ RS, No. 32/06, 98/07)

- Rules on limit values for intake of dangerous substances and fertilizers in soil (OJ RS 84/05)
- Rules on soil pollution caused by waste deposits (OJ RS, No. 3/03, 44/03, 41/04)
- Rules on waste incineration (OJ RS No. 32/00, 53/01, 81/02).

Every treatment and disposal option must satisfy clearly specified environmental quality criteria as shown in Table 1.

Table 1. Limit values of some chosen parameters, most often critical in sludge, according to different acts (in mg/kg$_{d.m.}$)

Quality parameter	Legislative acts				
	1	2	3		4
	In st. leachate*	In sludge**	In sludge#	In st. leachate	In sludge$
As	2	-	20/30	3	0.8
Cd	1	5	0.5/1.1	0.3	0.5
Cr	10	500	40/90	3	8
Cu	50	600	30/60	6	5
Hg	0.2	5	0.2/07	0.1	0.05
Ni	10	80	30/55	6	-
Pb	10	500	40/100	3	10
Zn	50	2000	100/300	1,8	100
TOC/DOC	18%/7500				

* *for non-hazardous, nondegradable waste*
** *for non-agricultural applications*
\# *agricultural/non-agricultural uses*
$ *DIN 51731*

GENERATION RATE

Construction of wastewater treatment plants essentially increased in the years since 2000, when Slovenia entered the process of accession to the EU. Correspondingly, it has strongly increased the amounts of residual sewage sludge (according to European Waste List denoted as 19 08 05). Similar sludges are generated also in industrial biological treatment plants (denoted as 19 08 12). Due to their similar properties, they may be treated or disposed of together by similar means. They will be considered together in this report.

Due to relatively dispersed population of Slovenia, there is also great dispersion of wastewater treatment plants in terms of location and size. Nearly 250 municipal wastewater treatment plants are now in operation, however only 10 % of them are larger than 10.000 PE (and only 5 larger than 100.000 PE). Their capacity is about 2 million PE (just as the population of Slovenia), however part of the capacity is covered by industrial effluents. There are also many industrial biological plants, facing the same problem of waste sludge disposal. An average sludge generation rate is 20 kg$_{d.m.}$/PE.year, thus, over 40,000 tons of dry matter or 200.000 tons of wet waste sludge can be expected every year in the country. Generation rate is shown in Table 2. The reported figure differs from expected value due to some primary sludge added to the secondary (biological) one.

Table 2. Sewage sludge generation in recent years in Slovenia

	Generation rate (t/y)*		
Year	**EWL 19 08 05**	**EWL 19 08 12**	**Together**
2002	14767	2882	17649
2003	20140	2772	22912
2004	26747	8843	35590
2005	39366	11889	51255
2006	46744	9897	56623

**water content not specified (usually from 15-25 %); EWL: European Waste List*

The annual amount of waste sludge (on wet basis) increases 15 %. This rate will level off during the next few years, since the construction of the largest plants has been almost completed.

The amount of wet sludge for disposal is being affected for two reasons:

- Raw sludge is stabilized by means of more and more efficient biodegradation processes (usually combination of anaerobic and aerobic digestion), that reduce the content of organic matter
- Separation of primary and secondary sludge is gaining importance due to different composition and related problems with disposal.

Both aspects contribute to reduction of the amount of waste sewage sludge for disposal, however at the moment it cannot yet match the increasing generation rate.

SLUDGE COMPOSITION

The typical chemical composition of the sludge and mean value of some biggest municipal wastewater treatment plants in Slovenia, is shown in table 3.

According to criteria from the Waste directive and Landfill directive this sludge may not be assigned as a hazardous waste. Increased values of some heavy metals (barium, copper, manganese, lead and especially zinc), however, present some obstacles to potential utilisation of sludge on land. Anions and organic compounds do not seem to be limited.

Table 3. Characteristic sludge composition and its standard leachate

Parameter	Unit	Analytical standard	Measured value
Dry matter (105ºC)	%	EN 12880	20.5
Volatiles (550ºC)	% d.m.	EN 12897	70
TOC	% d.m.	ISO 609	35
Antimony	mg/kg d.m.	EN ISO 17294-2	1
Arsenic	mg/kg d.m.	EN ISO 17294-2	2
Barium	mg/kg d.m.	EN ISO 17294-2	300
Beryllium	mg/kg d.m.	EN ISO 17294-2	0.2
Boron	mg/kg d.m.	EN ISO 17294-2	30
Cadmium	mg/kg d.m.	EN ISO 17294-2	1
Chromium tot.	mg/kg d.m.	EN ISO 17294-2	90
Cobalt	mg/kg d.m.	EN ISO 17294-2	7
Copper	mg/kg d.m.	EN ISO 17294-2	200
Manganese	mg/kg d.m.	EN ISO 17294-2	300
Mercury	mg/kg d.m.	EN ISO 17294-2	2
Nickel	mg/kg d.m.	EN ISO 17294-2	35
Lead	mg/kg d.m.	EN ISO 17294-2	150
Thallium	mg/kg d.m.	EN ISO 17294-2	<0.1
Tin	mg/kg d.m.	EN ISO 17294-2	2
Vanadium	mg/kg d.m.	EN ISO 17294-2	15
Zinc	mg/kg d.m.	EN ISO 17294-2	600
Chlorine tot.	mg/kg d.m.	EN ISO 17294-2	70
Sulphur tot.	% d.m.	EN ISO 17294-2	1
PCB	mg/kg d.m.	EN ISO 10382	< 0,05
AOX	mg/kg d.m.	DIN 38414-18	140
PAH	mg/kg d.m.	EPA M 610	0.04
Standard leachate, EN12457-4			
Antimony	mg/l		<0.01
Arsenic	mg/l	EN ISO 17294-2	< 0.05
Cadmium	mg/l	EN ISO 17294-2	< 0.003
Chromium tot.	mg/l	EN ISO 17294-2	< 0.05
Copper	mg/l	EN ISO 17294-2	< 0,1
Mercury	mg/l	EN ISO 17294-2	< 0.001
Molybdenum	mg/l	EN ISO 17294-2	0.1
Nickel	mg/l	EN ISO 17294-2	< 0.05
Lead	mg/l	EN ISO 17294-2	< 0.05
Selenium	mg/l	EN ISO 17294-2	<0.01
Zinc	mg/l	EN ISO 17294-2	< 0.5
Tot. dissolved matter	mg/l	EN 12880	2800
DOC	mg/l	ISO 8245	1700
Chlorides	mg/l	EN ISO 17294	40
Fluorides	mg/l	EN ISO 17294	0.2
Sulphates	mg/l	EN ISO 17294	30
pH	-	EN ISO 10523	7.7

SLUDGE TREATMENT

Stabilization

Fresh surplus sludge is biologically unstable and must be stabilized prior to disposal. At the moment, no direct use or disposal of fresh sludge is practiced in Slovenia. Stabilization can be achieved by aerobic (small wastewater treatment plants) or anaerobic processes (large plants). Especially small plants often practice stabilization in centralised plants (sludge is transported to larger centralized plants), which are more efficient and also facilitate final disposal.

Anaerobic stabilization (mesophilic digestion) of sludge is practiced relatively rarely (10 plants only), primarily on the larger scale, where biogas production contributes to the reduction of treatment costs. Some plants use combined input, composed of fresh sewage sludge, separately collected biodegradable municipal waste, food waste, etc… Biogas is utilised for power production and for heating of the digesters and treatment plant premises. The biggest treatment plant in the country uses all the produced biogas for heating up the digesters and drying the dehydrated sludge. Total electricity production totals up to 2.5 million kWh annually, with the trend toward increasing the production (IREET Ljubljana, 2007).

On average, the biological stabilization reduces the organic load of sludge by half, with a corresponding increase of the mineral content, including heavy metals and POP's.

Dehydration

Following the stabilization step, chemical treatment and conditioning is often needed before the dehydration process. For the latter, filter presses and belt filters are mainly used on small plants, whereas continuous centrifuges are used on large plants. Presses and belt filters are less efficient than centrifuges (20% and 30 % of dry matter in the dehydrated sludge, respectively).

FINAL MANAGEMENT OPTIONS

Table 4 shows the methods and sludge quantities, used in final treatment of the dehydrated sludge in Slovenia.

Internal methods

The main internal treatment methods of dehydrated sludge are direct land use and recycling after composting. These methods are used when certain utilization of dehydrated sludge is possible on the premises of treatment plants or their operators (mainly non-arable land). This type of sludge disposal can be performed only sporadically. Composting is practiced on-spot, in small scale, using structural materials, usually together with other types of municipal waste. The compost produced is used for maintenance of green areas around the treatment plants. Limited amounts of sludges are temporary stored, before the most appropriate (or cheap) method is found. Land use and composting is undoubtedly the simplest (as well as cheapest) way of sludge elimination.

Table 4. Treatment options of the waste sewage sludges in the Republic of Slovenia (2006)

Type of waste	Internal methods		External methods	
	Methods	**Quantities, t**	**Methods**	**Quantities, t**
19 08 05	Temporary storage	321	Temporary storage	589
	Recycling/Composting	2831	Recycling (composting)	4030
	Land use	3288	Landfill disposal	13967
			Export (to incineration)	21916
			Other disposal types	123
19 08 12	Recycling/Composting	218	Recycling (composting)	786
	Landfill disposal	686	Landfill disposal	1616
			Export (to incineration)	6424
			Other disposal types	149

External methods

The largest amount of sludge in the year 2006 was exported in granulated dry form for incineration. The reason for this impractical and expensive method is absence of proper incineration facilities in the country and tightening of the landfill requirements. The existing industrial thermal processes have not yet obtained permits to use the dry sludge as an alternative fuel. For cement kilns, which use large amounts of secondary fuels, the sludge is not particularly attractive due to its relatively low calorific value (about 11-12 MJ/kg at 90 % d.m.). Sludge export for incineration abroad may be, however, considered as a temporary solution. New thermal treatment facilities for wastes and sludges are currently under construction.

Landfill disposal of dehydrated sludge has been the most traditional way of disposal and, at the moment, the second most practiced. The trend is, however, declining due to stricter landfill acceptance regulation. As shown in the table 1, the acceptation criteria for landfills give strict limit values on content of heavy metals and total organic carbon in the sludge and its standard leachate (TOC and DOC respectively). Especially TOC/DOC limit values are difficult to reach by conventional digestion/composting stabilization processes.

External composting of dehydrated sewage sludge is most often performed in combination with biodegradable municipal waste and other structural materials (bark, corn stalks). The raw sludge is used to provide nutrients (mainly nitrogen), humid content and to regulate moisture. Compost is used in non-agricultural applications: for recultivation of disposal sites and degraded areas, public parks maintenance etc…

Other methods are less important. Land use is almost absent due to severe limitation of sludge use on arable land. The available arable areas are not abundant around the biggest cities, either. In Slovenia 36 % of land is agricultural and 60 % is covered with forests and woods.

Most frequently encountered limiting parameters are zinc, copper, chromium and lead.

COST OF DISPOSAL

Disposal cost differ very much (from 30-110 Euro/ton), depending on type of final method. The cheapest is land application (if only possible), followed by landfill disposal, then by secondary fuel utilisation and finally incineration.

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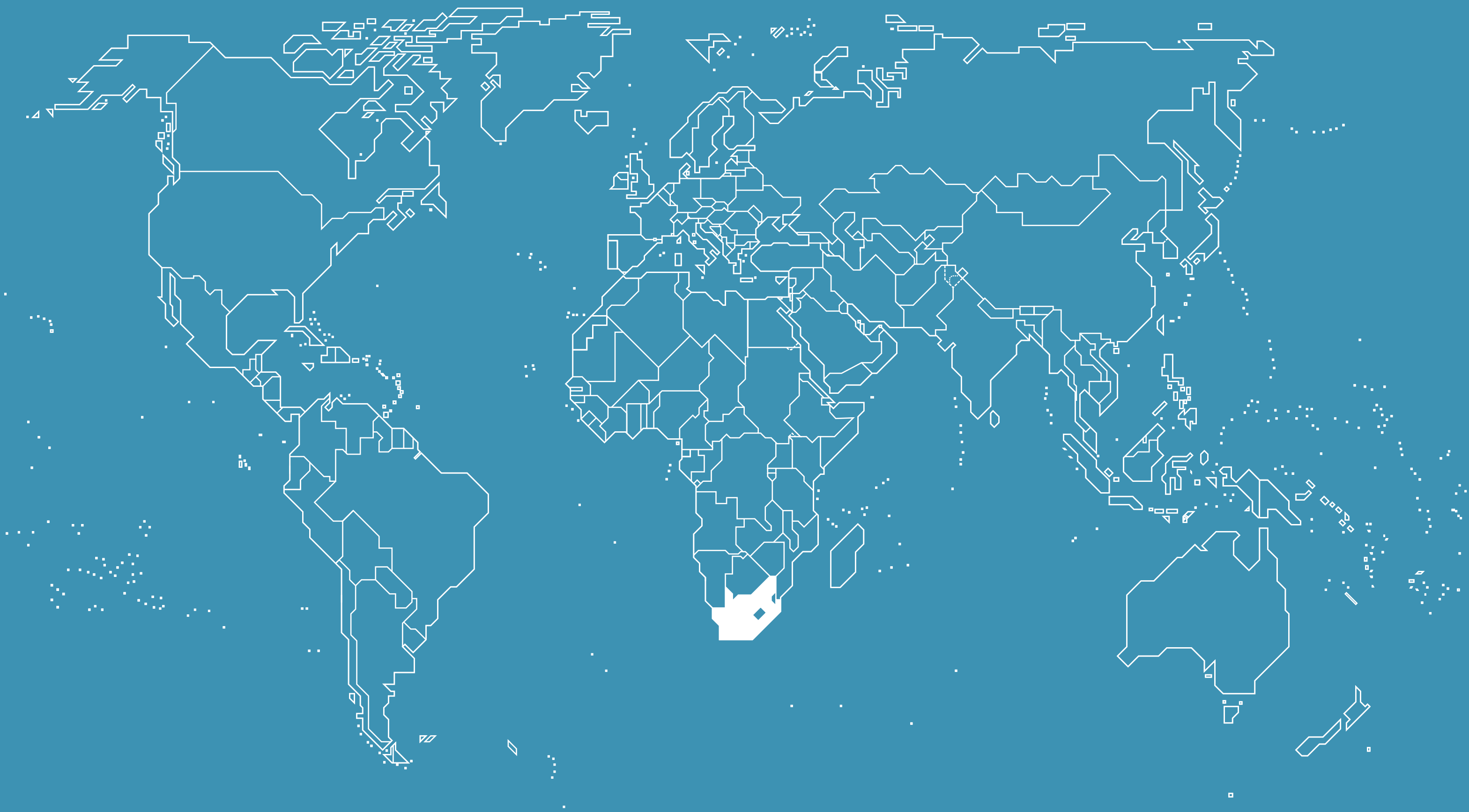

South Africa

Faecal sludge management

BACKGROUND

The use of on-site sanitation systems, such as septic tanks, bucket latrines and pit latrines, is implemented widely in both rural and urban areas in South Africa. The faecal matter, which is often contaminated with domestic waste, originating from these on-site sanitation systems requires responsible handling and disposal. In dense informal settlements of South Africa, the challenges are significant. The problems and challenges in faecal sludge management rest with all the components of the faecal sludge stream – viz. pit/vault emptying, transport, storage or treatment, and use or disposal. All aspects are involved, including institutional/managerial, financial/economic, socio-cultural, and technical.

CASE STUDY

In order to report on the typical management of Faecal Sludge in South Africa, the eThekwini Municipality (formally known as the Durban area) case is presented in this report.

eThekwini's population is around 3 million and the municipal area is 2 297 square kilometres. The eThekwini Municipal area occupies 1.4% of the total area of the province, but contains just over a third of the population of KwaZulu-Natal (one of the major provinces in South Africa) and 60% of its economic activity.

eThekwini Municipality decided to provide a basic package of sanitation and water in the form of a urine diversion (UD) toilet and a 200 litre yard tank to all households outside the reach of the waterborne sewage and unable to pay for water services. In 2002, around 140 000 households needed these systems. eThekwini installed 57 500 UD toilets by end of 2007. The current backlog is 31 500 for rural areas and 114 000 for informal settlements in urban areas.

The UD toilets were chosen for cost effectiveness and the fact that they are closed units and therefore prevent groundwater pollution. One of the major cost motivations for selecting UD over Ventilated Improved Pit (VIP) latrines was the cost of emptying the pits. The municipality spends on the order of R 70 million (US $ 8.75 million at current exchange rates) to empty the 100 000 existing pit latrines that required urgent emptying. Due to the terrain and inaccessibility of most pit latrines, the cost of emptying one pit latrine is between R 600 and R 1000 (75 – 125 US $), which is unsustainable, even for a large municipality.

UD technology separates the urine and faeces. The pathogens in the faecal matter are inactivated over time through the drying process. The dried faecal matter can then be safely removed by the household at no cost to the municipality. The UD toilets are constructed with two vaults or chambers. When the first vault is full, the pedestal is moved over to the second vault, and the first hole is sealed. When the second vault is full, the first vault is emptied and so on. The urine is diverted into a soak away.

Rural application

The UD toilets are seen as a viable option for rural applications. The main reason is that the rural community are accustomed to manure and working with farm animals and the UD toilet is therefore acceptable.

The emptying of the vaults is the responsibility of the household. Each household that receives a UD toilet was visited several times to educate it on the use of the technology as well as general hygiene. The householders normally dispose of the UD solid matter on site in a hole, which is covered. They have been educated not to spread it on land and were issued with gloves and a spade to manage the UD material.

The University of Kwa-Zulu Natal are researching several aspects related to the safety of the vault emptying for UD and VIPs, as well as studying the feasibility of the agricultural use of UD sludge in agricultural practices.

Urban application

The use of on-site sanitation solutions in peri-urban areas is more problematic. The emptying of the vaults requires large scale programmes. In this case, small businesses have emerged that provide a central pit emptying service or provide advice to households. Current research funded by the Water Research Commission is investigating the risks associated to the household owner when emptying a pit.

The municipality have committed to empty all VIPs once every 5 years. Officials are accurately mapping all VIPs that are emptied on a GIS system to allow for more accurate figures on the number of VIPs. Where VIPs are accessible with a tanker, they are emptied with a tanker. The rest are emptied manually using appropriate safety equipment.

The disposal of the faecal matter is proving to be challenging. If space allows, the faecal sludge is buried on site. Where this is not feasible, the sludge is blended into the waterborne system, which completely overloaded the wastewater treatment plant in at least one case. The municipality are also investigating other innovative institutional and technological solutions, such as franchising and deep trench disposal.

The medium term objective is to change all VIPs to UD technology with a view to connect the peri-urban areas to the water born system in the long term.

CONCLUSIONS

In South Africa, information on the extent of the problem with the management of faecal sludge from on-site sanitation units is clearly observed and local authorities attempt to address this through links with local research groups such as the University of KwaZulu-Natal, University of the Western Cape and the CSIR.

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Wastewater sludge management

BACKGROUND

The Republic of South Africa is located at the southern tip of Africa. It borders the Atlantic and Indian oceans and Namibia, Botswana, Zimbabwe, Mozambique, Swaziland, and Lesotho. Table 1 presents an overview of the demographics of the country.

Table 1. Demographic information – South Africa

Official language	11 (Afrikaans, English, isiNdebele, isiXhosa, isiZulu, Sepedi, Sesotho, Setswana, siSwati, Tshivenda, Xitsonga
Area	1 221 037 km^2
Population	48 million (2007)
Gross Domestic Product (GDP)	Total: US \$ 587.5 billion Per Capita: US \$ 13 300
Gini Coefficient	57.8 (high)
Human Development Index	0.674 (medium)
Climate	Semi-arid

South Africa has approximately 900 wastewater treatment plants, which treat on the order of 5 000 000 to 7 000 000 m^3/day (Derived from the South African Department of Water Affairs and Forestry data base). The size distribution of the plants is detailed in Figure 1.

Technology development has progressively addressed the requirements of public health protection, removal of solids and oxygen consuming compounds and removal of nitrogen and phosphorus to protect receiving water bodies against eutrophication. Wastewater treatment plant owners and operators use a wide spectrum of established and proven treatment technologies including:

- Suspended growth biological treatment processes, such as activated sludge plants;
- Fixed film biological treatment processes, such as biofilters/trickling filters and rotating biological contactors; and
- Integrated pond treatment technologies, such as anaerobic ponds, oxidation ponds etc.

There is little information on the sludge handling practices of the small plants, although it is suspected that most of the sludge is accumulated on site. The data presented in this section stem from the raw data collected as part of a countrywide survey of 72 wastewater treatment plants (Snyman *et al.*, 2004), which focused mainly on the plants larger than 2000 m^3/day. Figure 2 shows the types of sludge generated by the wastewater treatment plants surveyed on a mass percent bases. The majority of sludge that is used/disposed is anaerobically digested sludge (primary and humus sludge). Waste activated sludge accounts for 25% of the mass. Blended sludge represents primary and activated sludge blended before or after digestion.

Figure 1. Size distribution of wastewater treatment plants in South Africa

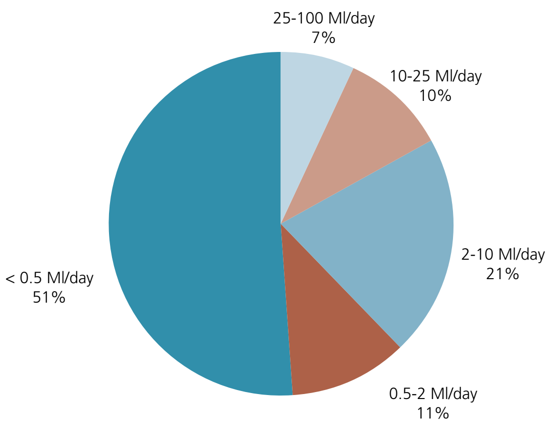

Figure 2. Sludge generated at wastewater treatment plants in South Africa (dry mass percent base)

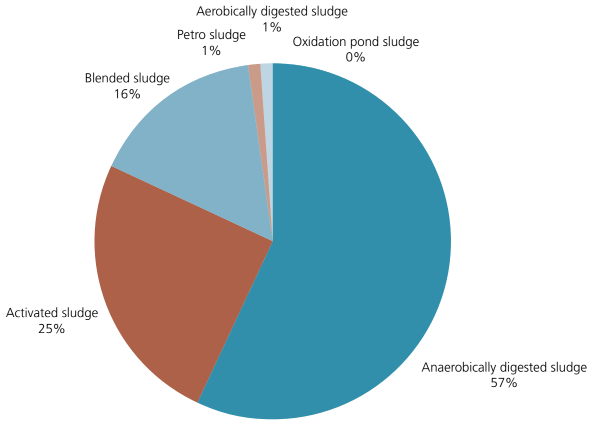

Figure 3. Dewatering technologies employed in South Africa (dry mass percent base)

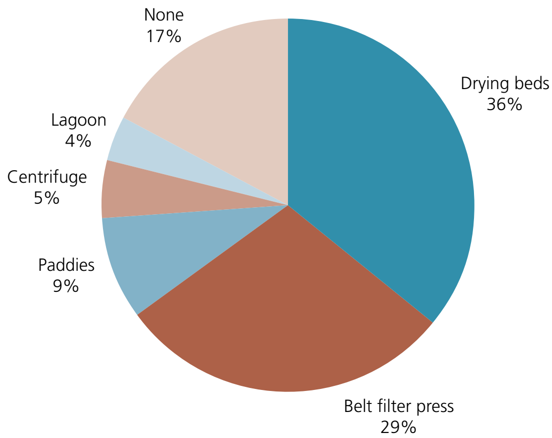

Figure 4. Tertiary treatment and additional stabilisation technologies employed in South Africa (dry mass percent base)

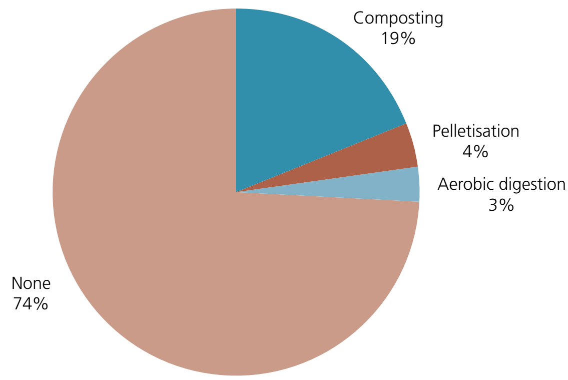

Figure 3 illustrates the dewatering technologies employed by the wastewater treatment plants surveyed in this study on a mass percentage basis. Most of the sludge mass is dewatered either in drying beds (36%) or mechanical belt filter presses (29%). Where no dewatering technologies are employed, liquid sludge is often used for direct land application such as dedicated land disposal and instant lawn cultivation. When comparing mechanical dewatering systems, the mass of sludge dewatered in belt filter presses exceeds that of centrifuges. If the data is reworked to represent the number of plants rather than the dry mass percentage, the figures are significantly different. Drying beds are used at 45% of the plants, followed by belt filter presses (15%), centrifuges (5%), paddies (9%), and lagoons (4%), while 24 % of the plants employ no dewatering (Snyman *et al.*, 2004).

Figure 4 illustrates the tertiary and additional stabilisation technologies used to stabilise the sludge. Anaerobic digestion of primary and humus sludge is still employed to stabilise the majority (57%) of the sludge in South Africa (Figure 2). The majority (74%) of the sludge mass did not treat the sludge further than the traditional anaerobic digestion and activated sludge extended aeration. Composting is used by both metropolitan city councils and plants in smaller town councils while pelletisation is only employed by large metropolitan councils, which is why the mass percentage is relatively high (19%). Only 9% of the number of plants surveyed composted the sludge. Aerobic digestion is employed as an additional treatment method after anaerobic digestion in one major site, which contributed 3% of the mass of total sludge surveyed (Snyman *et al.*, 2004).

Final disposal methods employed by the wastewater treatment plants surveyed in South Africa are still dominated by on-site disposal methods. This includes direct land application and stockpiling of the sludge on site. The beneficial uses of sewage sludge include: the use of the sludge by the local municipality or farmers, to generate compost, as the bottom layer for golf courses or to cultivate instant lawn. In some cases the sludge is sold or given to a contractor in exchange for bulking agent. The stockpiled sludge of many plants decreased over time without explanation (Snyman *et al.*, 2004).

LEGISLATIVE OVERVIEW

A brief overview of the South African Sludge Guidelines is required in order to comment on how the benchmark sludge is managed in South Africa.

The South African wastewater guidelines, of which Volume 1 and 2 were published in 2006, are now being implemented by the local authorities (Snyman and Herselman, 2006ab). The Department of Water Affairs and Forestry stipulates in the authorisation of the plant that the Guidelines should be adhered to and through this process the Guidelines become legally binding. The South African guidelines will ultimately comprise of a set of 5 Volumes:

- Volume 1: Selection of Management Options
- Volume 2: Requirements for the agricultural use of sludge
- Volume 3: Requirements for the on-site and off-site disposal of sludge
- Volume 4: Requirements for the beneficial use of sludge
- Volume 5: Requirements for the thermal sludge management practices and for commercial products containing sludge.

WASTEWATER SLUDGE CLASSIFICATION SYSTEM

Wastewater sludge is classified according to a microbiological, stability as well as a pollutant class (Table 2).

Table 2. The South African wastewater sludge classification system

Classification class	Best quality	Intermediate quality	Worse quality
Microbiological class	A	B	C
Stability class	1	2	3
Pollutant class	a	b	c

Microbiological limits

Table 3 shows the limits set for the different microbiological classes. Class A is based on the US EPA Part 503 rule (US EPA, 1993) Class A restrictions. The Microbiological Class B restrictions were selected to encourage achievable pathogen reduction targets (99% pathogen reduction, or a two log reduction). No pathogen reduction is required for Microbiological Class C. Typically, this microbial class is destined for disposal or incineration. The use of Microbial Class C sludge is not permitted unless adequate management options are implemented. The requirements for stability Class 1 or 2 should therefore constantly be met to avoid infection and nuisances.

Table 3. The South African wastewater sludge guidelines for microbiological aspects

Microbiological class	A		B		C
	Target value	Maximum permissible value*	Target value	Maximum permissible value*	No targets are set
Faecal coliform (MPN/g_{dry})	< 1000	<10 000	$< 1 \times 10^6$	$< 1 \times 10^7$	$> 1 \times 10^7$
Helminth ova (Total viable ova/g_{dry})	< 0.25 (or 1 viable ova/4g_{dry})	1	<1	4	>4

* *Note: A 90% compliance is required. Only 10% of the samples may fall between the target value and the maximum permissible value*

Stability limit

The stability classes were introduced based on the fact that the use of unstable sludge could influence public perception negatively, especially when sludge is used beneficially. Table 4 shows the different stability classes. The stability options are based on the vector attraction reduction options in the US EPA Part 503 Rule

Table 4. The South African wastewater sludge guidelines for stability aspects

Stability class	1	2	3
	Comply with one of the options listed below a 90 percentile bases.	**Comply with one of the options listed below a 75 percentile bases**	**No stabilisation or vector attraction reduction options required.**
Vector attraction reduction options (Applicable to Stability Class 1 and 2 only)			
Option 1	Reduce the mass of volatile solids by a minimum of 38 percent		
Option 2	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit		
Option 3	Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit		
Option 4	Meet a specific oxygen uptake rate for aerobically treated sludge		
Option 5	Use aerobic processes at a temperature greater than 40°C (average temperatures 45°C) for 14 days or longer (eg., during sludge composting)		
Option 6	Add alkaline materials to raise the pH under specified conditions		
Option 7	Reduce moisture content of sludge that do not contain unstabilised solids (from treatment processes other than primary treatment) to at least 75 percent solids		
Option 8	Reduce moisture content of sludge with unstabilised solids to at least 90 percent solids		
Option 9	Inject sludge beneath the soil surface within a specified time, depending on the level of pathogen treatment		
Option 10	Incorporate sludge applied to or placed on the surface of the land within specified time periods after application to or placement on the surface of the land		

Contaminant limits

The organic and inorganic pollutant limits and load restrictions vary for different applications. For example, the pollutant limits applicable for agricultural use of sludge will be completely different from those pertaining to landfill or incineration. The requirements for sampling and analysis would also be different for each option. The pollutant limits for the agricultural use of wastewater sludge are detailed in Table 5. The pollutant limits have been adapted from the US EPA Part 503 rule (US EPA, 1992, 1994).

No limits were set for the organic pollutants. This decision is based on international literature, the lack of local knowledge as well as the cost of these analyses. In order to start gathering local information, plants are requested to do a once off measurement of the poly aromatic hydrocarbons (PAHs). However, monitoring of PAH is not required.

Wastewater sludge that complies with a Pollutant Class a may be used in agricultural practices without doing soil analyses as long as agronomic application rates (up to a maximum load of 10 ton/ha/year) are not exceeded. Wastewater sludge with a Pollutant Class b may be used in agricultural practices if the soil testing indicates that the assimilative capacity of the soil has not been exceeded. The soil limits (Table 6) were based on extensive research of international findings as well as local research findings (Herselman and Steyn, 2001; Herselman, *et al.,* 2005). Wastewater sludge with a Pollutant Class c may not be used in agricultural practices.

Table 5. Pollutant limits for the agricultural use of wastewater sludge in South Africa

Aqua regia extractable metals (mg/kg)	Pollutant class		
	a	**b**	**c**
As	< 40	40-75	> 75
Cd	< 40	40-85	> 85
Cr	< 1 200	1 200 –3 000	> 3 000
Cu	< 1 500	1 500-4 300	> 4 300
Pb	< 300	300-840	> 840
Hg	< 15	15-55	> 55
Ni	< 420	420	> 420
Zn	< 2 800	2 800-7 500	> 7 500

Note: A 90% compliance is required to comply with a pollutant class.

Table 6. Metal limits for soils amended with wastewater sludge

	Total investigative level (mg/kg) (aqua regia extraction)	Total maximum threshold (mg/kg) (aqua regia extraction)	Maximum available threshold (mg/kg) (NH_4NO_3 extraction)
Cd	2	3	0.1
Cr	80	350	0.1
Ni	50	150	1.2
Pb	56	100	3.5
Zn	185	200	5.0
Cu	100	120	1.2
Hg	0.5	1	0.007
As	2	2	0.014

MANAGING THE DEFINED BENCHMARK SLUDGE IN SOUTH AFRICA

The benchmark sludge/biosolid

Consider a theoretical South African wastewater treatment plant that treats 20 000 m³/day. This equals a population equivalent of 100 000, assuming the unit wastewater generation of 200 ℓ/person/day – people equivalent includes the industrial and commercial wastewater discharged to municipal treatment plants.

The raw wastewater sludge quality provided as the benchmark is considered. This particular sludge will be classified a Class C3a sludge (Microbiological Class C – Table 3, Stability Class 3 – Table 4 and Pollutant Class a – Table 5). According to the South African sludge guidelines, the only permissible use for the sludge as it is, would be dewatering and thermal treatment.

However, the Guidelines encourage sludge producers to use wastewater sludge beneficially especially for Pollutant Class a sludges.

The raw primary sludge (benchmark sludge) will therefore typically be stabilised through anaerobic digestion (especially for this size plant). A few of the larger plants (p.e. > 100 000) use composting or pelletisation and the smaller plants will use long term (> 7 years) storage in lagoons for stabilisation especially in warm dry areas.

The anaerobic digestion will stabilise the sludge through Vector Attraction Reduction Option 1 or 2 to achieve a Stability Class 1. The resulting sludge classification will be Class C1a or B1a depending on the pathogen reduction achieved (Microbiological Class C or B – Table 3, Stability Class 1 – Table 4 and Pollutant Class a – Table 5). Table 7 lists the permissible uses and restrictions for Class C1a and B1a sludge.

Table 7. Permissible use/disposal options for a Class C1a and B1a sludge.

Use or disposal option	Class C1a sludge	Class B1a sludge
Agricultural use at agronomic application rates	Permissible with crop restrictions and restrictions regarding the management practices and the site due to the microbiological class.	Permissible with crop restrictions and restrictions regarding the management practices and the site due to the microbiological class. These restrictions are less onerous compared to the Microbiological Class C restrictions.
On-site and off site disposal	Permissible although it is discouraged. General rules and restrictions apply to protect all receptors. Onerous licensing process.	Permissible although it is discouraged. General rules and restrictions apply to protect all receptors. Onerous licensing process.
Beneficial use – other than agricultural use at agronomic rates: Once off and continuous high rate land application Use of wastewater sludge in the landfill cover mix Rehabilitation	Permissible with restrictions and requirements to prevent pathogen migration in the water environment and to protect human health.	Permissible with restrictions and requirements to prevent pathogen migration in the water environment and to protect human health.
Commercial use (selling it to the broad public)	Not permissible. Only Class A1a sludge may be distributed or sold to the public.	Not permissible. Only Class A1a sludge may be distributed or sold to the public.

The Pollutant Class a ensures the unrestricted use of sludge and no soil testing is required as long as the guidelines are followed. The benchmark soil data provided indicates that even a Pollutant Class b sludge could be used in land application (Table 6).

ECONOMIC INFORMATION

The costs of operations based on 2008 figures:

- Typical proportion of sewerage operation costs attributable to sludge in South Africa can be up to 50% for both Capital as well as Operations & Maintenance.
- User charge to customers for treatment of sewage varies, depending on the institutional models followed.
- Cost of 1000 liters of diesel fuel: ZAR 7960 (US $ 1000, based on current exchange rates).

- One kilowatt hour electricity: ZAR 0.285 c/kWh (Excluding 14% Value Added Tax). Approximately US $ 0.035/ kWh. Significant energy cost increases are anticipated due to the energy shortages that recently emerged in South Africa.

ON-SITE AND OFF-SITE DISPOSAL

The on-site disposal of sludge is still practiced widely, especially in the smaller urban centres. Alternative, beneficial uses are encouraged through the publication of the new South African sludge guidelines. There are now also specific guidelines that deal with the on-site and off-site disposal of sludge (Volume 3: Requirements for the on-site and off-site disposal of sludge) which set strict requirements for different disposal options: waste piles, lagoons, dedicated land disposal and landfill, which (will hopefully) make these options less attractive financially. The disposal of sewage sludge into the marine environment is not permitted, although existing permitted deep sea marine disposal pipelines are licensed to discharge preliminary treated wastewater.

INCINERATION

Incineration of sewage sludge is not widely practiced in South Africa. The eThekwini Metropolitan is currently commissioning an incinerator, as marine disposal and agricultural options are limited.

AGRICULTURAL USE

South African soils are typically carbon depleted. Wastewater sludge is therefore considered a resource in terms of the carbon content as well as its nutrient value. The agricultural use of wastewater sludge is widely applied and controlled by legislation and good practice guidelines (Volume 2: Requirements for the agricultural use of sludge; Volume 4: Requirements for the beneficial use of sludge). Considering the benchmark sludge, the use of the raw sludge will not be permissible for agricultural purposes. Raw sludge has to be stabilised before use to achieve Stability Class 1 or 2 (Table 4). In terms of the metal content, the use of the benchmark sludge is permissible at agronomic rates without restrictions as long as the application rate of 10 ton/ha/year is not exceeded. Crop restrictions would apply due to the microbiological content.

Typically, the sludge producer manages the contract with the user and delivers the sludge to the land free of charge. The farmers will then mix the sludge into the soil. In cases where the sludge producers manufacture palletised products, it is sold commercially.

Once-off and continuous high rate application of sludge to land is also permissible with more stringent restrictions compared to the use of sludge at agronomic rates. Since sludge improves not only the physical characteristics of soils, but also provides essential nutrients and micro elements, it is used for the rehabilitation of disturbed/degraded soils (nutrient depletion, erosion, acidity and salinity, poor physical properties, reduced biological activity) after mining activities, intensive farming and industrial activities and the establishment of golf courses, race courses, vineyards, road embankments, public parks etc.

PRODUCTION OF PRODUCTS

A few of the metropolitan areas manufacture commercial fertilizer and compost. Since these products are sold/distributed to the general public, management of the product is out of the hands of the producer. Therefore, these products should be of such quality that they can be used without restrictions and adverse environmental and human health implications. All commercial products must conform to Class A1a. Other commercial products manufactured from sludge and/or incinerator ash are used in the construction industry (mainly bricks). The production of vetrified glass products, constructed materials, fuel pellets, oil and protein is locally limited to research projects.

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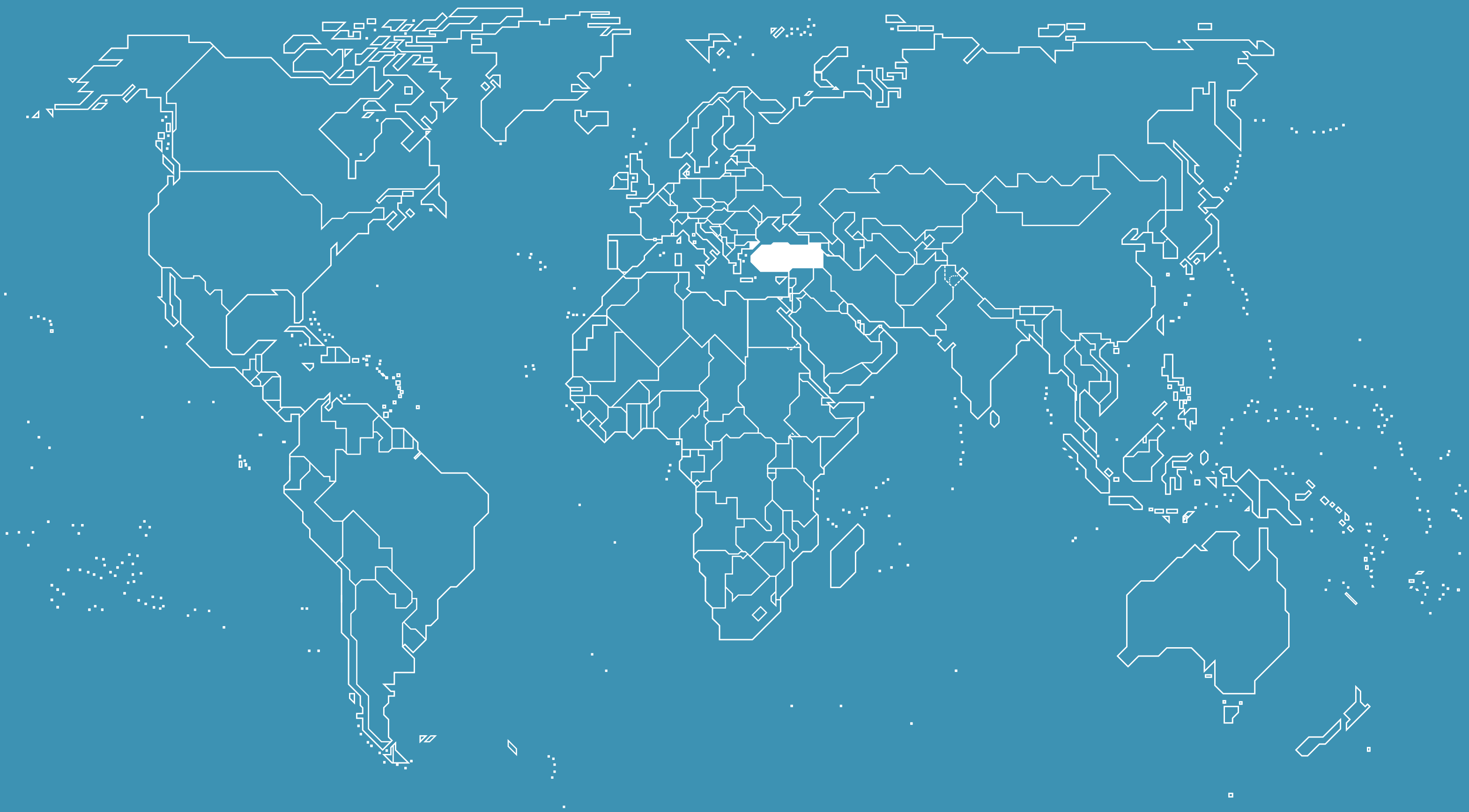

Turkey

Authors: Dr. Ayse Filibeli, Dr. Azize Ayol

Sludge/biosolid management in Turkey

From point view of practical applications by local authorities and legal aspects of turkish environmental policy on sludge/biosolid treatment and handling

BACKGROUND

On the road of Turkey's accession to the European Union, great structural improvements were made to Turkey's administration of environmental legislation for pollution prevention, covering many environmental fields, such as water and wastewater treatment, air pollution control, and waste management. Turkey published the priority list in the Turkish National Programme for Adoption of the EU Acquis (Official Gazette No. 25178 of 24.07.2003). In enforcement of environmental regulations, extensive upgrading has been also done on sludge management, which is still included in the priority list. Further efforts have also been in progress in many areas, including industrial and hazardous waste management.

The Ministry of Environment and Forestry (MEF) is mainly responsible for environmental legislation and policy development in Turkey. The Ministry of Environment was established in 1991 and merged with Ministry of Forest in 2003. MEF, with its local staffs in provinces, guarantees legal arrangements on environmental protection. It is the only authority regarding the related matters, drafting laws and supervising their execution process as well as enabling the commencement of research activities in the environmental protection field. Recently, MEF published the "First National Communication on Climate Change of Turkey" (FNCCC), implemented by United Nations Development Programme (2007) (Filibeli and Ayol, 2007). Beyond the ministry, other ministries, such as the Agricultural Ministry, are in charge of integrating environmental policy targets too. In addition to ministries and their local staffs, municipalities have also established their own administrative structures, such as water and sewerage administrations in the cities of Istanbul (ISKI Establishment Law, 1982), Izmir (IZSU Establishment Law, 1987), and Ankara (ASKI Establishment Law, 1986). Apart from the authorities, the administration, namely Bank of Provinces (formerly Municipalities Bank), is mainly responsible for municipality investments on water and sewerage systems was established in 1933 to provide funds and technical supports to the municipalities for their investments in the framework of the national development programmes. Municipalities had water and wastewater treatment systems built, depending on the technical requirements of Bank of Provinces. Recently, these responsibilities shifted to the Greater Municipalities included small municipalities in their own structures according to Greater Municipalities Law.

Considering the National Environment Law (LE, #2872), enacted in 1983 and amended in 2006 as a milestone in environmental protection in Turkey, many regulations and laws have been put in place to regulate environmental limitations in many aspects, including treatment, discharging, disposal, and recycling (Official Gazette No: 18132 of August 9th, 1983). The LE has many regulations – Water Pollution Control Regulation, Air Pollution Control Regulation, Solid Waste Control Regulation, Environmental Impact Assessment Regulation, Soil Pollution Control Regulation, Hazardous Waste Regulation, and Urban Wastewater Treatment Regulation – in accordance with the European Union Directives, and also covers technical legislation for practical applications. These regulations have been revised and updated according to EU Directives in the accession process of Turkey to the EU. Although the LE does not have any special regulation or technical legislation on sludge management, some special articles and limitations on sludge management exist in the present regulations. Further, MEF has made some efforts and preparations to have a special regulation on sludge management (www.cevreorman.gov.tr, Filibeli and Ayol, 2007).

Turkey, with approximately 70.5 million people, has 16 greater municipalities, more than 3,200 municipalities, and more than 37,000 villages. Regional differences in population distribution have been significantly observed. While most people have settled in big cities in the western part of Turkey, municipalities with a population of less than 1,000,000 are located in the central part. A total of 70.5% of the population lives in the cities (TUIK 2007). Based on the population served by the sewerage systems, the connection rate is almost 63%. The rates of population served by sewerage systems and wastewater treatment plants in the total municipal population are 86% and 45%, respectively. Although a small part of the sewerage systems are in operation as combined systems, most of them have been constructed as separate systems.

The first wastewater treatment plant in Turkey with a capacity of 751 000 m^3/year was constructed in 1982. The planning and construction of wastewater treatment plants (WWTPs) have been the subject of much consideration by municipalities because of public pressure and consciousness on environmental problems. By the end of 1994, the total number of WWTPs with a capacity of 602 Mm^3/year was 45. Most of them (41 WWTPs) were biological treatment plants, which have 37.35% of total treated water amount. The rest of them had only physical treatment units with a capacity of 62.65% of the total capacity. Between 1994 and 2004, the number of constructed plants was drastically increased, reaching 172. The total capacity of the WWTPs was 3 410 Mm^3/year by the end of year 2004. The amount of wastewater treated by the treatment plants is about 1901 Mm^3/year. Most of them have primary and secondary treatment units (91% of total capacity) while a few have advanced treatment units (TUIK 2007).

Early sludge treatment applications in WWTPs have trickling filters and conventional activated sludge systems, as biological treatment units were sludge drying beds followed by aerobic sludge stabilization. Sludge drying beds without aerobic stabilization had been used for extended aeration activated sludge units. Dried sludges had been landfilled or used for agricultural purposes. Regarding the strict limits for discharging effluents to the receiving media, population growth rates, environmental requirements, advanced treatment units for nutrient removal have been established for the last decade. Further, most of the WWTPs in operation were upgraded to provide the limitations. The new plants also included advanced sludge handling processes like anaerobic stabilization units and mechanical dewatering equipment (Filibeli and Ayol, 2007).

Based on 2004-Statistical Environmental Data of TUIK, the ratio of population served by wastewater treatment plants to the total population is given as 37%. Assuming solids production as 60 g/P.d, the amount of municipal sludges can be estimated as 1 600 tones/day. The produced municipal sludges are commonly stored in municipal solid waste landfill areas, and spread to the land for agricultural usage. Currently, sludges produced in municipal or industrial wastewater treatment plants have been processed using auxiliary sludge treatment processes like thickening (gravity thickening, flotation thickening, and centrifuge), stabilization (biological-aerobic or anaerobic processes and lime stabilization), and dewatering (sludge drying beds, belt press filters, centrifuges, and plate press filters).

Depending on the final sludge/biosolid quality, they can be stored in landfill areas or used for agricultural purposes. For land spreading or agricultural usage, liquid sludge application is prohibited by the National Regulations, while the cake sludge processed in stabilization units (biological or alkali stabilization) can be used if its quality falls within the regulation's limits. However, there are many deficiencies in practice in sludge stabilization, which is the most important part of sludge handling for many reasons such as the reduction of pathogens and odor emissions. Greater Municipalities, particularly, have wastewater treatment plants that have had very good experiences with anaerobic digester units, including Ankara MWWTP, Kayseri MWWTP, Malatya MWWTP and Tuzla/Istanbul MWWTP. The plants use the biogas obtained from their anaerobic digesters to supply the energy requirements of almost the entire plant. Many medium-scale municipalities have also aerobic digesters in their WWTPssuch as Manisa MWWTP. As another stabilization alternative, sludge composting with municipal solid wastes as a final disposal method has been used. Apart from these methods, the lime stabilization method is applied in many treatment plants' successive dewatering units. This application leads to increases in sludge amounts, which is unfavorable, particularly, for big cities.

SELECTION OF DISPOSAL PRACTICE

Using 2004- TUIK Environmental Data and the assumption given above (60 g/PE.d), the total municipal sludges production is about 1600 dry tonnes/day (≅580000 dry tonnes/year). Based on population equivalent, the produced sludge amounts as kg/PE.year and m^3/PE.year are given in Table 1 according to the applied treatment processes.

Table 1. The produced sludge amounts according to the applied treatment processes

Wastewater treatment process	Total treated wastewater amount (Mm^3/year)	Dry matter production (kg/PE.year)	Sludge/biosolid production assuming 25% dry matter (m^3/PE.year)
Primary treatment	599	13	0.051
Secondary-biological treatment	1071	22	0.086
Advanced treatment	231	33	0.129
TOTAL	1901		

Depending on the geographic regions of Turkey and population differences in the regions, some of the Municipal Wastewater Treatment Plants (MWWTPs) were selected to represent sludge characteristics. The sludge analyses results of the plants are summarized in Table 2. This table covers some basic information about the plants and the parameters given the Turkish Soil Pollution Control Regulation (SPCR)-Appendix- IA, which is critical for beneficial uses of sludge in agricultural areas. Beyond the parameters given in the SPCR, the whole analyses results of different plants located in different regions are also shown in Table 3.

The selection of disposal methods differs from plant to plant, depending on technical requirements in legislation; local social, cultural and weather conditions; and economic factors, such as transportation and operation costs. The most common disposal alternative in Turkey is landfilling for processed sludges, either in special areas or in municipal solid waste disposal areas. The second alternative for them is sludge composting with organic portions of municipal solid wastes or other wastes like livestock waste. The technical requirements for compost quality are given in Turkish Solid Waste Control Regulation. The composted product meets the reclamation purposes in recreational areas if it is sufficiently hygienic. Beyond these methods, land application for agricultural purpose has been given great attention, recently. Because of the rich nutrition content of sludge/biosolids, use of sludge for agricultural purposes has been increased, especially in the poor quality soils as a fertilizer or soil conditioner. Many municipal WWTPs have done their research and practices in grasslands located in their own plants. Other alternatives of beneficial usage of sludge are still under research by universities, governmental institutions, and management of the plants. For example, pilot scale biodiesel production applications have been applied by using the biosolid to grow oil seed plants.

Table 2. Analyses results of sludge characteristics for different MWWTPs located in different regions of Turkey

Parameters	Izmir Cigli MWWTP (2007) – IZSU[a]	Kayseri MWWTP-KASKI (2005)[b]	Malatya MWWTP-MASKI[c]	Ankara MWWTP (2004)-ASKI[d]	SPCR limits
Pb (mg/kg DS)	85.96	201	28.6	82.7	1,200
Cd (mg/kg DS)	3.4132	6.5	1	2.6	40
Cr^{+3} (mg/kg DS)	200.96	732	90	216	1,200
Cu (mg/kg DS)	305.64	521	106	185.5	1,750
Ni (mg/kg DS)	73.256	309.5	41	93.5	400
Hg (mg/kg DS)	<1	1.2	0.66	3.8	25
Zn (mg/kg DS)	1017.4	1552	448	1887	4,000
N (mg/kg DS)	-	39523	-	-	-
P (mg/kg DS)	-	5068	-	-	-
pH	-	6.7	-	-	-
Conductivity (µS/cm)	-	1316	-	-	-
Organic matter (%)	-	61	-	-	-

Parameters	Izmir Cigli MW-WTP (2007) – IZSU[a]	Kayseri MWWTP-KASKI (2005)[b]	Malatya MWWTP-MASKI[c]	Ankara MWWTP (2004)-ASKI[d]	SPCR limits
Information about the plants	Located in Western part of the country, Current flowrate: 600000 m3/day, treatment process: advanced treatment Sludge treatment units: Sludge storage, thickening (dewatering table), centrifuge, lime stabilization Sludge disposal method: Landfilling	Located in Central part of the country, Current flowrate: 110000m3/day, treatment process: advanced treatment Sludge treatment units: Gravity Thickening (pre and post), anaerobic digestion, belt-filter press dewatering Sludge disposal method: Landfilling	Located in Eastern part of the country, Current flowrate: m3/day, treatment process: advanced treatment Sludge treatment units: Gravity Thickening (pre and post), anaerobic digestion, belt-filter press dewatering Sludge disposal method: Landfilling	Located in Central part of the country, Current flowrate: 665000m3/day, treatment process: biological treatment Sludge treatment units: Gravity Thickening (pre and post), anaerobic digestion, belt-filter press Sludge disposal method: Landfilling	

Table 3. Whole analyses results of sludge of different MWWTPs

Parameters	Izmir Guneybati WWTP-IZSU(2007)[a]	Kayseri MWWTP-KASKI (2005)[b]	Konya Basarakavak MW-WTP (2005)[e]
pH	7.98	7.56	6.45
Salinity, %	2.43	-	2.4
Dry matter content (@ 65 °C), %	70.15	-	91
Organic matter content, %	45.51	53.5	52
Organic Carbon, %	26.4	-	25.94
Total Nitrogen, %	1.68	4.2	2.4
Total Phosphorus, %	0.68	0.42	1.10
C/N	15.71	6.94	10.8
K, %	0.49	0.33	1.29
Ca, %	1.3	4.76	4.24
Mg, %	0.98	0.81	0.96
Na, %	0.51	0.25	0.12
Fe	2.52 (%)	-	5219 (mg/kg)
Cu, mg/kg	70.2	304.8	88
Zn, mg/kg	300	1076	237
Mn	0.48 (%)	186 (mg/kg)	375 (mg/kg)
Br, mg/kg	28.4	-	-
Co, mg/kg	26	-	-
Pb, mg/kg	34.2	-	-
Cr, mg/kg	34.2	-	-
Ni, mg/kg	62.1	-	-
Cd, mg/kg	1.24	-	-
Fecal coliform (MPN/g)	-	1.5 x10^5	-
Salmonella (25 g)	-	Not detected	-
Information about the plants	Located in Western part of the country, Current flowrate: 17000 m3/day, treatment process: advanced treatment Sludge treatment units: Thickening (dewatering table), beltfilter press Sludge disposal method: Compost	Located in Central part of the country, Current flowrate: 110000 m3/day, treatment process: advanced treatment Sludge treatment units: Gravity Thickening (pre and post), anaerobic digestion, belt-filter press dewatering Sludge disposal method: Landfilling	Located in Central part of the country, Current flowrate: 300 m3/day, treatment process: extended aeration activated sludge Sludge treatment units: Sludge storage in lagoons Sludge disposal method: Landfilling

ECONOMIC INFORMATION

The costs of operations for a typical municipal wastewater treatment plants based on 2007 budgets and costs are as follows:

- Typical proportion of sewerage operation costs attributable to sludge are 45% Operations & Maintenance (O&M)
- Charge to customers for treating 1 m^3 sewage: 0.45 YTL
- Total operational cost for treating sewage: 5.0 – 7.5 YTL/PE.year
- 1 liter of diesel fuel: 2.76 YTL
- One kilowatt hour electricity: 0.13 YTL (1YTL = 1.3US$, 1 YTL = 1.7 Euro)

LANDFILL OPTION

Most of the sludge/biosolids generated from WWTPs have been stored in landfill areas where the nearest municipal solid waste disposal area to the WWTP is. Technical limitations on transportation and disposal of sludge in landfills are given in the Turkish Solid Waste Control Regulation (SWCR). This regulation has many articles and restrictions on sludge management. SWCR covers limitations for transportation, land-filling, incineration, and composting of sludges produced by either municipal or industrial wastewater facilities. For instance, if sludge is in liquid form (more than 65% water content), it cannot be stored in a municipal solid waste landfill area (Official Gazette 20814 of 1991 and amended No 25777 of 2005). However, the national environmental policy focused on the beneficial uses of sludge for many purposes, including reducing the required capacities of the landfill areas, energy recovery from sludge, etc. In addition to SWCR, the Hazardous Waste Regulation (HWR) gives the strict limitations for wastes to be landfilled. According to the HWR, sludges that contain hazardous materials such as PCBs, cyanide, phenolic substances, etc. can not be disposed of in landfills (Official Gazette, 22387 of 1995, updated 2005). If any sludge is classified as hazardous waste, it can be disposed in special sites. Sludge/biosolids samples have been analyzed according to the HWR before landfilling. If the results do not exceed the limitations, they can be landfilled. All authorities on water and sewage systems of the cities should regularly submit the analyses results to MEF to get the required permissions (Turkish Regulation on Urban Wastewater, which is the same as Directive 91/271/EEC). The most important problem in this area is that the sludge/biosolids have generally high "Dissolved Organic Carbon (DOC)" values. This situation is a major challenge for most of the municipalities. Table 4 summarizes the analyses results of the municipal and domestic sludges for four WWTPs. As can be seen from this table, DOC values of eluat samples and Total Organic Carbon (TOC) values of original sludge samples exceed the limits of HWR. This is a common problem for some plants, even if they have stabilization units – aerobic or anaerobic digesters. The research and studies to solve the problem are still going on.

Table 4. The analyses results of four WWTPs according to HWR landfilling criteria

Parameters to be analyzed in eluat*	Izmir Cigli MW-WTP IZSU[a]	Izmir Foca MWWTP-IZSU[a]	Istanbul Tuzla MWWTP (2004)-ISKI[f]	Istanbul Pasa-koy MWWTP (2004)-ISKI[f]	Limits of HWR
As	0.035 mg/L	0,031 mg/L	<0.003	0.032	<0.2-2.5 mg/L
Ba	0.615 mg/L	0,013 mg/L	<0.5	<0.5	<10-30 mg/L
Cd	<0.01 mg/L	< 0,010 mg/L	<0.0005	0.0006	<0.1-0.5 mg/L
Total Cr	0.165 mg/L	< 0,010 mg/L	<0.02	0.34	<1-7 mg/L
Cu	0.02 mg/L	< 0,010 mg/L	0.083±0.004	0.3	<5-10 mg/L
Hg	<0.01 mg/L	< 0,010 mg/L	<0.0005	0.0008	<0.02-02 mg/L
Mo	0.01 mg/L	0,011 mg/L	0.007	<0.005	<1-3 mg/L
Ni	0.76 mg/L	0,050 mg/L	0.205	0.21	<1-4 mg/L
Pb	0.02 mg/L	< 0,010 mg/L	<0.001	0.7	<1-5 mg/L
Sb	<0.01 mg/L	< 0,010 mg/L	—	<0.006	<0.07-0.5 mg/L
Se	<0.01 mg/L	< 0,010 mg/L	0.003	<0.001	<0.05-0.7 mg/L
Zn	0.58 mg/L	0,043 mg/L	0.313±0.02	0.94	<5-20 mg/L
Cl^-	1625 mg/L	900 mg/L	19±2.2	30.8	<1500-2500 mg/L
Fl^-	1.61 mg/L	12,09 mg/L	0.4±0.07	0.33	<15-50 mg/L
$SO_4^=$	1362 mg/L	122 mg/L	4±0.18	34	<2000-5000 mg/L
DOC	2312 mg/L	1.800 mg/L	—	1973	<80-100 mg/L
TDS (Total Dissolved Solids)	1760 mg/L	6.228 mg/L	1810	3000	<6000-10000 mg/L
Phenol index			0.09±0.013	<0.05	
Parameters analyzed in original waste					
TOC	273169.8 mg/kg	167520 mg/kg	—	56868	60000 (6%) mg/kg
BTEX (benzen, toluen, ethlybenzen, xylenes)	-	-	—	2.53	
PCBs	-	-	—	<0.01	
Mineral oil	-	-	11344 mg/kg	35947	
LOI (Loss of ignition)	-	-	56%	50	10000 (10%)
Information about the plants	Located in Western part of the country, Current flowrate: 600000 m3/day, treatment process: advanced treatment Sludge treatment units: Sludge storage, thickening (dewatering table), centrifuge, lime stabilization Sludge disposal method: Landfilling	Located in Western part of the country, Current flowrate: 4500 m3/day, treatment process: advanced treatment Sludge treatment units: Sludge storage, thickening (dewatering table), beltfilter press Sludge disposal method: Landfilling	Located in Northwestern part of the country, Current flowrate: 150000 m3/day, treatment process: advanced treatment Sludge treatment units: Sludge storage, thickening (dewatering table), centrifuge, lime stabilization Sludge disposal method: Landfilling	Located in Northwestern part of the country, Current flowrate: 125000 m3/day, treatment process: advanced treatment Sludge treatment units: Sludge storage, thickening (dewatering table), centrifuge, lime stabilization Sludge disposal method: Landfilling	

** The samples prepared from dried sludge according to Turkish Standards-TS EN 12457 and DIN 38414 S4, German Standard Methods for Researching Water, Effluent Water and Sludge, Group S: Sludge and Sediments; Determining Leaching with Water (S4) (1984).*

AGRICULTURAL USAGE

Turkey has soil that is poor in nitrogen, phosphorus, other micro elements, and organic matter in general (Okur and Delibacak, 1996). This situation causes use of treated sewage sludge/biosolids with their high macro- and micro-nutrition elements, high organic matter content as a fertilizer in the soil. Since sludge/biosolids include micro-elements like Fe, Zn, Mn, Mo, Cu and B, in addition to the macro elements (N, P, K), it can be substituted for commercial fertilizer. Turkey's soil has, by and large, high alkali content and almost 93% of the country has soil with pH above 6.5. It allows using of treated sludge/biosolid in agricultural land with some restrictions defined by Turkish Soil Pollution Control Regulation (SPCR) (Filibeli et al. 2001, Filibeli and Ayol, 2007). The analyses results of soil in different regions of Turkey are given in Table 5. The SPCR came into force in 2002 and was amended in 2005. It covers technical aspects and restrictions on soil pollution prevention techniques, sludge disposal and its agricultural usage. The regulation gives limitations and general principles for raw sludge, treated-stabilized sludge, and compost material (Official Gazette No. 25831 of 31.05.2005). The SPCR also gives the maximum allowable heavy metal limits of sludge for agricultural usage. The SPCR is almost the same as European Council Directive (86/278/EEC), which covers agricultural usage of sludges. Appendices (I A, I-B, and I-C) of the SPCR regarding the limitations for soil and plants systems are given in the following tables (Tables 6-8). Liquid sludge usage for land application and agricultural purpose is not permitted according to the legislation.

Table 5. Analyses results of soil in different regions of Turkey

Parameters	Kayseri- Central Anatolia[b]	Malatya Eastern Anatolia[c]	Gediz Plain- Aegean Region (Delibacak and Okur, 2000)
Pb (mg/kg DS)	18	< 10	7.89-2957
Cd (mg/kg DS)	0.5	<2	0.38-1.38
Cr^{+3} (mg/kg DS)	7.6	62	11.28-6501.(Total Cr)
Cu (mg/kg DS)	12.8	29	7.09-28.23
Ni (mg/kg DS)	38	57	-
Hg (mg/kg DS)	0.13	0.03	-
Zn (mg/kg DS)	68	48	22.50-87.50
Fe (mg/kg DS)	-	-	12019-35498
Mn (mg/kg DS)	-	-	20947-83787
N (mg/kg DS)	723	1360	-
P (mg/kg DS)	774	916	-
pH	8.9	8.7	7.11-8.67
Conductivity (µS/cm)	64.3	-	
Organic matter (%)	10	11	0.21-3.10

**Table 6a. Soil pollution parametrs and their limits
heavy metal limits in the soil (App. I-A of SPCR)**

Heavy Metals	pH 5 – 6 mg/kg Dry Solids	pH>6 mg/kg Dry Solids
Lead	50 **	300 **
Cadmium	1 **	3 **
Chromium	100 **	100 **
Cupper*	50 **	140 **
Nickel*	30 **	75 **
Zinc *	150 **	300 **
Mercury	1 **	1.5 **

**MEF can raise by up to 50% the permitted upper limits for soils with pH higher than 7 in the cases where there is no doubt about human and environmental health, especially when there is no seepage into the ground water. ** The permitted levels can be exceeded for soils where fodder plants grow and it has been scientifically shown that there was no harmful effect on human and environmental health.*

Table 6b. Limitations for polluted soil after treatment

Parameters	Limits
Cl^- (mg/L)	25
Na (mg/L)	125
Co (mg/kg dry soil)	20
As (mg/kg dry soil)	20
Mo (mg/kg dry soil)	10
Sn (mg/kg dry soil)	20
Ba (mg/kg dry soil)	200
Fl^- (mg/kg dry soil)	200
CN^- (mg/kg dry soil)	1
Complex CN^- (mg/kg dry soil)	5
$S^=$ (mg/kg dry soil)	2
Br (mg/kg dry soil)	20
Benzen (mg/kg dry soil)	0.05
Butyl benzen (mg/kg dry soil)	0.05
Toliol (mg/kg dry soil)	0.05
Xylol (mg/kg dry soil)	0.05
Phenol (mg/kg dry soil)	0.05
Se (mg/kg dry soil)	5
Talium (mg/kg dry soil)	1
Uranium (mg/kg dry soil)	5
PAH (mg/kg dry soil)	5
AOX (mg/kg dry soil)	0.5
Insecticides – Indiviual (mg/kg dry soil) Insecticides –Total (mg/kg dry soil)	0.5 2
PCB (mg/kg dry soil)	0.5
Hexaclor benzol (mg/kg dry soil)	0.1
Pentaclor benzol (mg/kg dry soil)	0.1
Ψ- HCH (lindan) (mg/kg dry soil)	0.1

Table 7. Maximum heavy metal limits of stabilized sludge/biosolid to be applied to soil (App. I-B of SPCR)

Heavy Metals	Limit values (mg/kg dry material)
Lead	1200
Cadmium	40
Chromium	1200
Cupper	1750
Nickel	400
Zinc	4000
Mercury	25

Table 8. Maximum permissible avaerage annual rate of heavy metal additions over a 10-year period (App. I-C of SPCR)

Heavy Metals	Limitations for Loading of sludge/biosolid applied to the soil (gr/da/year, dry matter) *
Lead	1500
Cadmium	15
Chromium	1500
Cupper	1200
Nickel	300
Zinc	3000
Mercury	10

** The permitted levels can be exceeded for soils where fodder plants grow and it has been scientifically shown that there was no harmful effect on human and environmental health.*

INCINERATION

Incineration as a final disposal method is not common in Turkey. Only one big plant, namely IZAYDAS, established in 1997 for all hazardous wastes, industrial sludges, etc., is properly working in Izmit/Kocaeli, Marmara Region. This plant has had a license from MEF since January 2002. However, there is no incineration plant for municipal and domestic sludges/biosolids.In addition, studies in terms of legislation and pilot scale trials have been done for beneficial uses of sludge as supplementary fuel in cement factories. This issue is regulated by the Legislation on General Rules for Waste Usage as Supplementary Fuel (Official Gazette No: 25853, 2005). Even some cement producers have a license from MEF for this; research on sludge cake characteristics – whether it affects the cement quality or not in the case of usage of sludge as a fuel source in cement factories is going on. The research has focused on conservation of natural sources and reducing fossil fuel needs. To transport sludge cakes to factories, high quality dewatering technology should be applied. For this reason, many authorities that are responsible for WWTPs are seeking drying technology alternatives. As representative values about the calorific value of sludge in Turkey, the data from two plants shows 2.500 kcal/kg of sludge from Kayseri MWWTP and 3.890 kcal/kg of sludge from Izmir Cigli MWWTP. Regarding the calorific values, combustion can be considered as an option. However, incineration is very expensive technology for Turkey.

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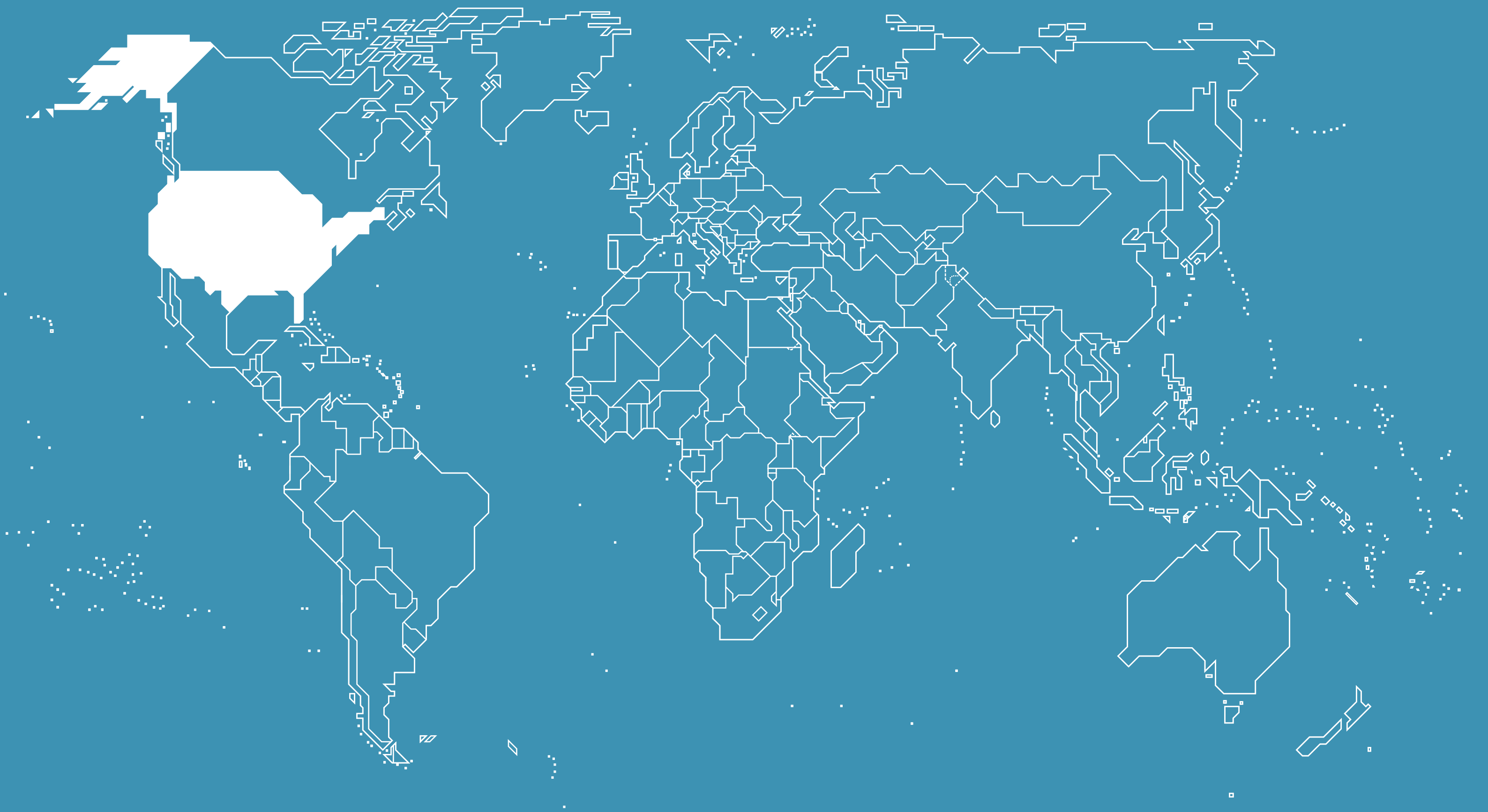


USA

Summary of wastewater treatment solids management in the United States

Complete report available at www.nebiosolids.org

In the United States (USA), centralized wastewater treatment facilities service a majority of the U. S. population's sanitation needs. However, most rural and some suburban populations rely on on-site wastewater treatment systems – septic systems. In most states, the majority of solids pumped from septic systems ("septage") is transported to wastewater treatment facilities for final treatment.

The infrastructure that leads to the production of sewage sludge (also called "wastewater solids," and – when treated and tested – "biosolids") includes 16,583 wastewater treatment facilities, according to the Environmental Protection Agency (USEPA). Of these, the largest ~3,300 generate more than 92% of the total quantity of wastewater solids produced in the USA (Table 1).

The treated solids – biosolids, removed from wastewater at these wastewater treatment facilities – can be legally used or disposed of in three ways: by application to soils to grow turf and crops, by landfilling (or surface disposal), and by incineration. The Clean Water Act provides the legal basis for management of biosolids nationwide, and regulations created by USEPA at 40 CFR Part 503 (Part 503) establish minimum national standards that are protective of public health and the environment. Each local wastewater treatment facility makes its own decision regarding how its solids are managed.

Data compiled from state regulatory agencies, USEPA offices, individual wastewater treatment facilities, and other sources indicate that 7,180,000 dry U. S. tons (6,514,000 metric tons) of biosolids were beneficially used or disposed of in the fifty states in 2004. Overall, current data suggest little change nationwide, since the late 1990s, in the rate of biosolids recycling to soils (USEPA, 1999), and half of state biosolids coordinators report that the amounts of biosolids applied to soils are not increasing in their states.

Table 1. Treatment facilities in operation in 2004 *(courtesy of Robert K. Bastion, USEPA)*

Existing flow range (mdg)	Number of facilities	Total existing flow (mdg)	
0.000 – 0.100	6,830	298	(0.9%)
0.101 – 1.000	6,431	2,327	(6.9%)
1.001 – 10.000	2,771	8,766	(26.1%)
10.001 – 100.000	503	13,233	(39.3%)
100.001 and greater	41	9,033	(26.8%)
Other[b]	7	-	-
Total[c]	16,583	33,657	(100%)

[b] *Flow data for these facilities were unavailable.*

[c] *Totals include best available information from States and Territories that did not have the resources to complete updating the data or did not participate in the CWNS2004.*

BIOSOLIDS QUALITY

According to federal and state regulations, before they are used as soil amendments or fertilizers, biosolids must be tested for regulated pollutants (e.g. heavy metals); in addition, the rate of application is usually limited by the nutrient needs of the crop being grown.

Under 40 CFR Part 403, USEPA requires local wastewater treatment facilities to implement and enforce industrial pretreatment programs aimed at reducing inputs to sewage systems of substances that could negatively impact the functions of the facility and the quality of the effluent and solids. These industrial pretreatment programs, and other efforts at controlling toxic substances, have resulted in significant reductions in the levels of heavy metals and some organic chemical contaminants in U. S. biosolids over the past three decades.

There is considerable robust data on the quality of biosolids with regards to heavy metals and other pollutants. The compilation of such data is difficult on a national scale. The best sources of information regarding the concentrations of heavy metals and other pollutants in biosolids are papers in the scientific literature.

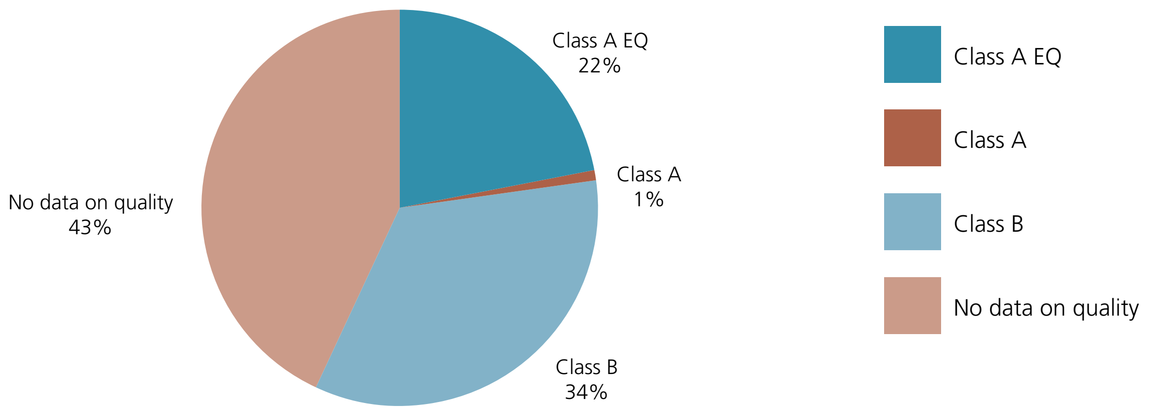
Data regarding unregulated elements (e.g. boron, silver) and unregulated organic chemicals are less available, but, where they do exist, they can be voluminous. Some states, such as Maine and New Hampshire, require biosolids to be tested for scores of compounds on at least an occasional basis. Such data is sometimes compiled and reported in state agency documents. Many larger public wastewater treatment facilities conduct testing on their biosolids for many different parameters to ensure product quality (e.g. Milorganite® and Boston's MWRA fertilizer pellets).

The Part 503 regulations designate two levels of pathogen treatment: Class A and Class B. Of the total 7,180,000 dry U. S. tons of biosolids in 2004, approximately 23% were treated to Class A standards (Figure 1) – and almost all of that was Class A EQ ("exceptional quality," having low metals, etc.). These biosolids can generally be used for a wide variety of purposes with few or no restrictions.

Another 34% of U. S. solids were treated to Class B standards. Class B biosolids contain reduced levels of pathogens and can be utilized in restricted ways, most commonly in agricultural operations with limited public contact.

For the remainder of U. S. biosolids (43%), there is no data (or no data was obtained) regarding whether or not it met Class A or Class B standards. This lack of data is mostly due to the fact that wastewater solids that are landfilled or incinerated are not generally subjected to the same stabilization, testing, and reporting requirements. There are some treatment works that produce Class A biosolids (e.g. heat dried pellets) that are burned in incinerators and can provide an energy recovery benefit.

Figure 1. Biosolids treatment level 2004 U.S. totals



USE & DISPOSAL OF BIOSOLIDS IN THE U. S.

Of the total 7,180,000 dry U. S. tons (6,514,000 metric tons) of wastewater solids produced in the U. S. in 2004, approximately 55% were applied to soils for agronomic, silvicultural, and/or land restoration purposes, or were likely stored for such uses. The remaining 45% were disposed of in municipal solid waste (MSW) landfills, surface disposal units, and/or incineration facilities (Figures 2 & 3).

Figure 2. Biosolids use and disposal practice 2004 U.S. totals

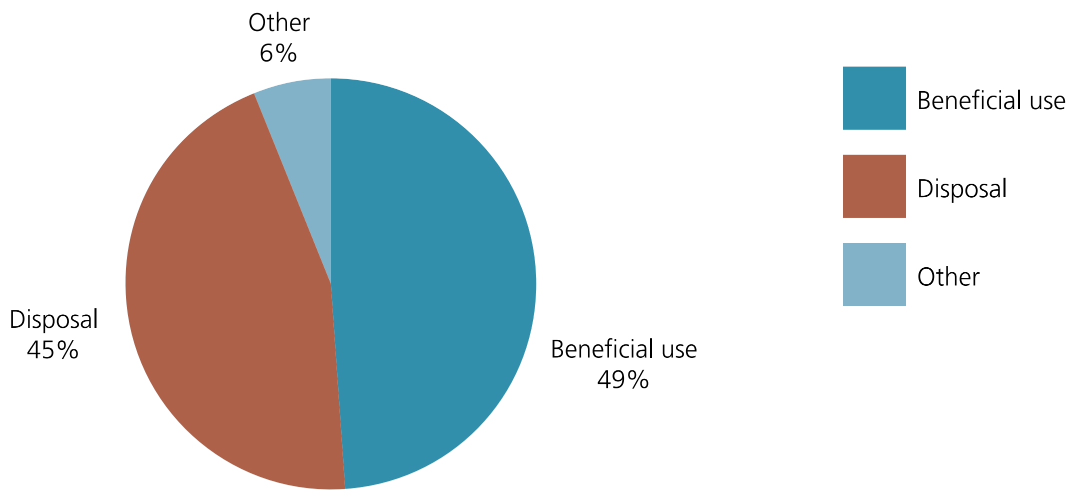
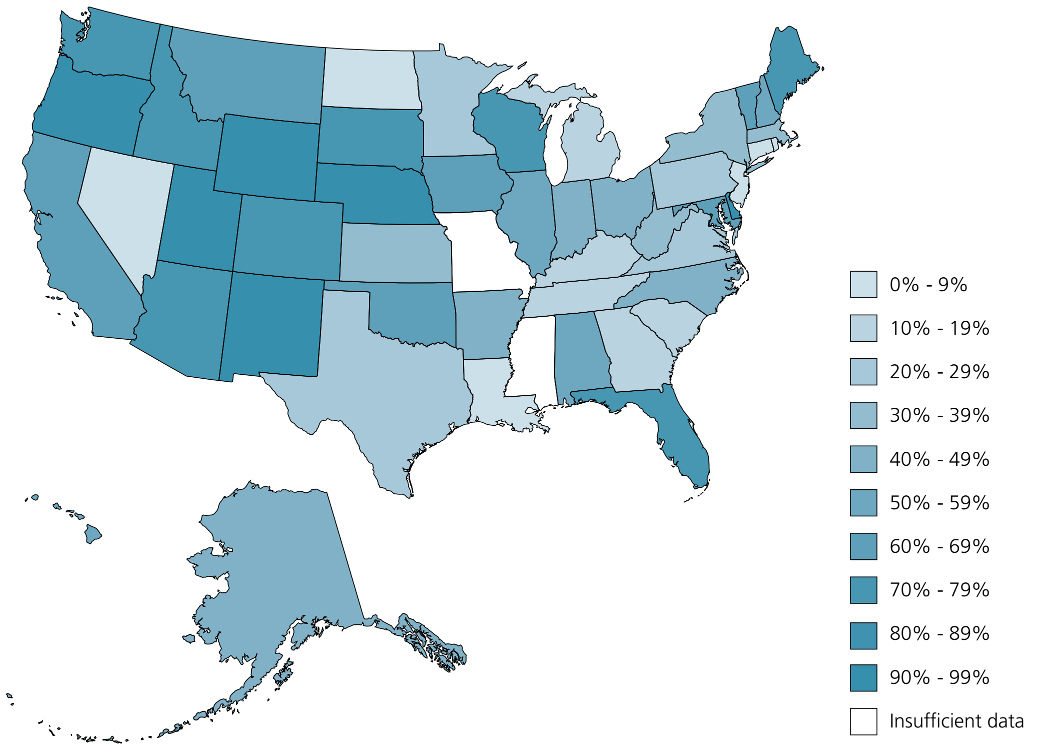


Figure 3. Percent biosolids beneficially used by State, 2004



Agricultural uses of biosolids dominate beneficial use practices in the U. S. (Figure 4). Most of this is Class B land application, but a good portion is Class A – at least 613,000 dry U. S. tons. The distribution of Class A "Exceptional Quality" (EQ) biosolids makes up one quarter of the U. S. total and includes significant amounts of biosolids compost and heat-dried pellet fertilizer. Reclamation – the use of biosolids to improve disturbed or marginal soils and lands (e.g. mine lands) – requires relatively large amounts of biosolids per acre of land, but only 3% of beneficially used biosolids are land applied for this purpose. Some biosolids that were specified as having been applied to rangeland are included in the "forestland" category; clearly, silvicultural uses of biosolids are limited.

Figure 4. Biosolids use and disposal practice 2004 U.S. totals

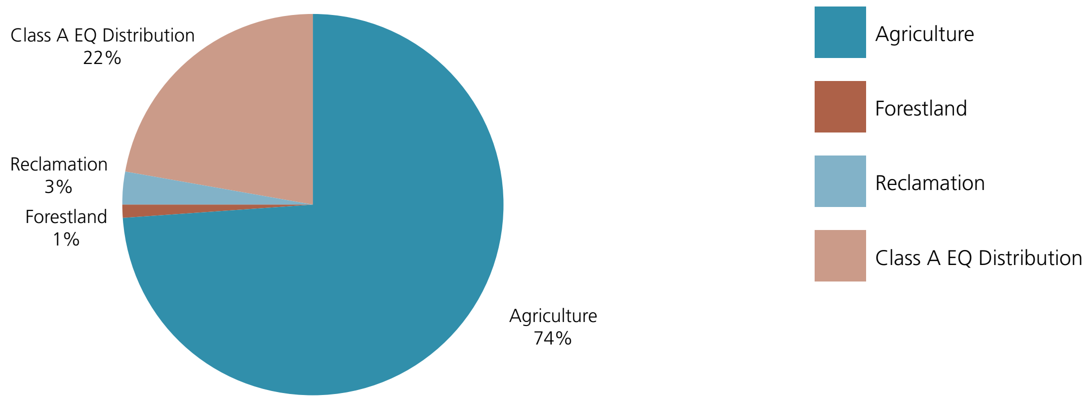
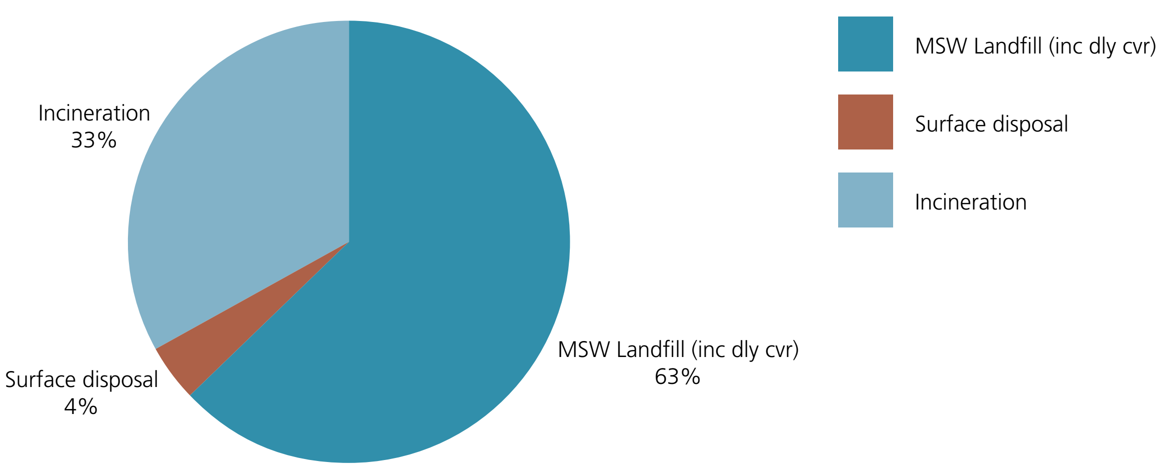


Figure 5. Disposal practices 2004 U.S. totals



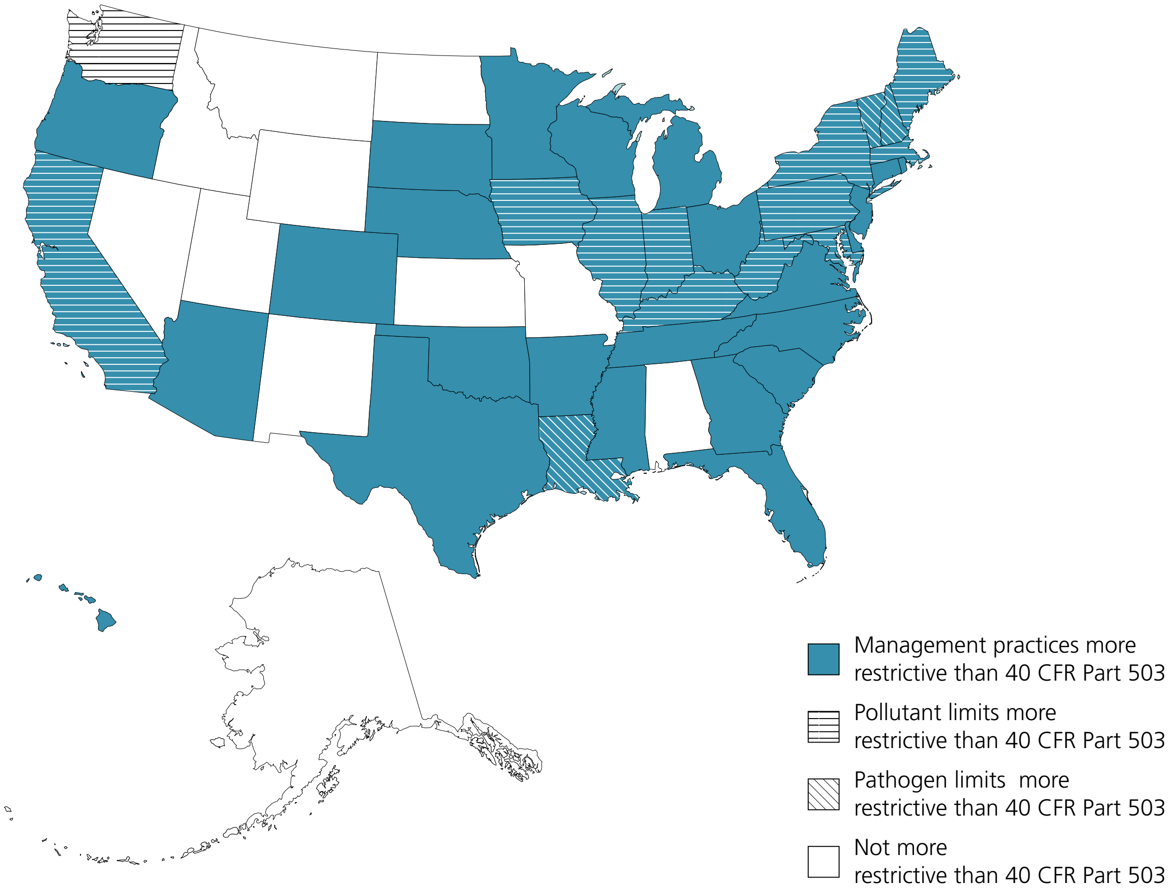
Most U. S. wastewater solids that are not applied to soils go to municipal solid waste (MSW) landfills (Figure 5). The 63% landfilled reported here for 2004 includes some that was used as alternative daily cover. Incineration (thermal oxidation) of wastewater solids predominates in a few densely populated states (e.g. Connecticut, Rhode Island) and manages large volumes of solids in several other states (e.g. at Anchorage, AK; Cleveland, OH; and Indianapolis, IN). In 2004, there were 234 operating incinerators in the U. S. Dedicated surface disposal units, also known as monofills, handle only a small percentage of the nation's wastewater solids.
Other uses of biosolids in the U. S. include:

- utilizing methane from digestors to produce energy;
- recovering heat from sludge incinerators;
- using biosolids incinerator ash as clean daily cover at landfills, as a soil conditioner, in cement and asphalt, and as clean fill material; and
- recovery of energy (in the form of methane) from landfilled biosolids ("bioreactor landfills").

STATE REGULATIONS

Most U. S. states have additional regulatory programs that go above and beyond the national U. S. EPA Part 503 regulations (Figure 6). Thirty-seven states require management practices for land application that are more stringent than those in Part 503, and sixteen have adopted pollutant (e.g. heavy metals) limits that are more stringent than those in Part 503. Seven states have received formal delegation for administration of Part 503, and most state regulatory programs work with relatively up-to-date regulations and are addressing current issues.

Figure 6. As of today, are your state's biosolids regulations more restrictive than 40 CFR Part 503?



TREATMENT TECHNOLOGIES

In the U. S., there is a diversity of technologies used to manage the solids (sewage sludges) removed during the treatment of wastewater. In order to allow for efficient handling and transport, they are stabilized and, in most cases, dewatered. Stabilization processes generally reduce putrescibility and potential odors, as well as pathogen and vector-attraction levels. Dewatering processes convert solids that are at least 95% water to a semi-solid material that is from 50% to 85% water. The data provided (Table 2) gives a sense of the relative abundance of different treatment technologies.

Table 2. Relative abundance of different biosolids treatment technologies in the U. S.

Technology	Reported Estimates of Number of TWTDS Using*…	Estimated Quantity of Biosolids Produced Using*…
Stabilization Technology		
Aerobic Digestion	2200	85,000
Digestion-anaer./other	1000	1,217,000
Lime/Alkaline	900	285,000
Long-term (lagoons, reed beds, etc.)	500	97,000
Composting	200	471,000
Thermal (not incineration)	60	112,000
Other	20	5,400
Dewatering Technology		
Belt Filter Press	650	415,000
Drying beds	400	380,000
Centrifuge	150	880,000
Plate & Frame Press	50	65,500
Vaccuum Filter	20	4,200
Screw Press	10	3,400
Other	40	600

**CAUTIONS IN USING THIS DATA: These are minimum estimates from incomplete data from states and other sources. They serve only to provide a rough sense of the relative importance of various technologies.*

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United States Environmental Protection Agency

According to U.S. census data, the US population is forecasted to double in the next 72 years and population growth results in increased human waste; biosolids production amounts will increase in tandem with population growth. As populations grow, municipalities are forced to find solutions for treating increased volumes of wastewater. Additionally, as more wastewater is treated, the wastewater solids separated during the treatment process create a new challenge, what to do with the increased volume of residuals. Options currently available to facilities for dealing with biosolids residuals include incineration, surface disposal, and land application. EPA publicly supports land application when conducted in compliance with federal and local regulations, but municipalities make decisions concerning what management option is best for the community.

Since the creation of the United States Environmental Protection Agency (EPA) in 1970, the Agency has had a policy of encouraging the recycling and reuse of materials and wastes. A recent example includes EPA's Comprehensive Procurement Guidelines (CPG), a key component of the government's "buy-recycled" program. The Resource Conservation and Recovery Act (RCRA) requires procuring agencies to buy recycled-content products designated by EPA in the CPG. A CPG update published in September 2007 revised the compost designation and added fertilizer made from recovered organic materials, including biosolids, to the landscaping products category. All federal agencies, and any state or local government agencies or government contractors that use appropriated federal funds, are required to purchase the designated items. For more information, visit *www.epa.gov/epaoswer/non-hw/procure/about.htm*.

Sustainable management of residual material is in the public interest. For example, according to USDA Agricultural Statistics, humans require enough calories per day to meet their energy needs. Where do we obtain our calories? Our calories are obtained from agriculture – farming and livestock production. Agriculture (land cultivation) accounts for over 98% of our food in the US. Aquatic systems contribute less than 2% of this food. The US is essentially self-supporting in matters of food production, but there are indications of potential concern. There are currently 1.5 acres of arable land per capita in the US. Each individual needs 1.2 acres to provide a diverse diet, suggesting that the land is reaching its food-production capacity.

This demonstrates the importance of biosolids recycling. Biosolids add nutrients and organic material to soils that help to improve soil structure and moisture retention. Biosolids also add beneficial physical properties by buffering soil pH to a desirable range and by improving soil. Land application sites include forests, reclamation sites, parks, golf courses, lawns and gardens, and agricultural land. About 7.2 million dry tons of sewage sludge are used or disposed of annually in the United States. About 55% of that is applied to the land (e.g., agriculture, reforestation, mining reclamation, and landscaping). The remaining 45% of the sewage sludge produced annually is either incinerated or placed in a surface disposal unit.

Biosolids are currently applied to less than 1% of arable land in this country. Thus, there is opportunity for growth and expansion for the recycling of biosolids to farmland to assist in improving the food-production capacity per acre so that we can continue to receive needed calories and balanced nutrition. In fact, land application of biosolids in compliance with federal and state laws is an environmentally sound and cost-effective option for communities to consider. Nutrients in biosolids provide savings in fertilizer costs. Commercial inorganic fertilizer (not from biosolids) production requires large amounts of energy and the use of fossil fuels and foreign oil. Recycling wastewater treatment products makes sense not only economically but environmentally as well.

In 1993, EPA promulgated the Standards for the Use or Disposal of Sewage Sludge. This rule is referred to as 40 CFR Part 503, as modified. This rule protects public health and the environment through a number of means as described below:

- ***General requirements***: Information on biosolids characteristics and biosolids land application and disposal sites that must be transferred between parties (preparers, generators and appliers) to ensure that all requirements of Part 503 are met.
- ***Numerical standards***: These are based on a 14 pathway multimedia risk assessment to develop numerical standards to protect humans, plants and animals from pollutants contained in or released from biosolids.
- ***Management practices***: These requirements describe the conditions under which the biosolids are placed on the land and any restrictions on the placement of biosolids on biosolids land application sites.
- ***Operational standards***: These consist of pathogen and vector-attraction reduction requirements applied to biosolids. The pathogen reduction options offer the biosolids land applier the choice of Class A (pathogen-free) biosolids without site controls or Class B biosolids (reduced pathogen content) with supplemental appropriate site controls. The vector-attraction reduction operational standards consist of a choice of options for reducing opportunities for vectors (e.g., rodents and insects) to contact and transmit pathogens.
- ***Monitoring***: There are requirements to monitor data on biosolids quality, operational standards, management practices, and site controls where appropriate. The frequency of monitoring depends upon the quantity of biosolids applied to the land on an annual basis.
- ***Record keeping***: Both preparers and appliers are required to keep the appropriate records for monitored data.
- ***Reporting***: There are requirements for certain classes of treatment works to report their records to the Permitting Authority on an annual basis.

States have adopted, in some cases, more stringent standards or management options. In addition, the States are encouraged to apply to EPA to gain the authority to implement the Part 503 requirements through their State permitting programs. In this way, the States can determine which projects deserve priority in oversight and permitting that are appropriate to local conditions.

The science of biosolids and land application has evolved over the 14 years since the Part 503 rule was issued. This is a good thing and the wastewater and biosolids community supports increased inquiry. EPA is committed to further inquiry, not out of concern that there is evidence that such inquiry is needed, but because there are areas in which our knowledge needs enhancing and because the public is better served by more comprehensive information. As is true in most science, truth and information are our friends. All current indications are that further inquiry will offer additional reassurance as to the viability of biosolids land application. Should it not, we want to know that too. The primary beneficiaries of biosolids land application are the public itself and its municipal governments. For them and for us, public health protection and environmental stewardship are paramount.

In 2002 the National Academy of Sciences released a report *Biosolids Applied to Land, Advancing Standards and Practices*. This report recommended research and other activities to reduce the scientific uncertainty involving biosolids land application. In response to that report, EPA developed an action plan in 2003 that included 14 projects aimed at reducing the scientific uncertainty and improving the biosolids program. EPA's biosolids activities since 2002 have focused on a number of activities, some either completed or ongoing. These activities include a sewage sludge survey, improved analytical methods for pathogens and pathogen indicators, quantitative microbial risk assessment, incident investigation in partnership with other agencies, investigating radioactivity in biosolids, and biennial reviews pursuant to requirements of the Clean Water Act, Section 405(d), to name a few.

EPA's biosolids program strives to continue improving biosolids processes and related information. An evaluation of the concerns of our partners and stakeholders shows that certain questions or challenges rise to the surface concerning various aspects of biosolids regulations and management. These include, but are not limited to, understanding pathogen destruction and treatment effectiveness, evaluating the effectiveness of Part 503 harvesting and grazing restrictions for Class B biosolids, determining the relevance of current indicators, and developing improved methods for detecting and quantifying pollutants. To follow up on the 2003 Biosolids Action Plan, EPA continues to identify the key issues, the primary areas of focus, and the projects and timeframes that will provide the guiding direction for the Biosolids Program over the next few years.

The Agency's biosolids blueprint for the next few years includes activities that are designed to:

- ***Advance our understanding of science, technology, and risk***: The biosolids program will investigate potential problems caused by the use or disposal of biosolids and conduct research into existing and emerging areas of concern.
- ***Communicate the best available information***: Because there continue to be significant public questions about the risk associated with land application of biosolids and the protectiveness of Part 503, EPA needs to communicate more effectively with the public about what we do not know about biosolids. Our focus is to build better communication tools that will make information publicly available as we know it.
- ***Meet EPA's statutory obligations***: Section 405 of the CWA requires EPA to conduct biennial reviews to determine what pollutants may be in biosolids and the risk they may pose. If appropriate, EPA would issue new or revised Part 503 regulations.

Land application of biosolids in compliance with federal and state laws is an environmentally sound option for communities to consider. Agricultural use is a cost-effective solution, which is beneficial to soil, provided that the levels of contaminants in biosolids will continue to decrease. For larger cities where available land is limited and the quality of biosolids is questionable, energy recovery may be a better alternative. Methods to recover other resources such as phosphorus in wastewater are promising but can be further improved and become more efficient in order to achieve future sustainable biosolids management.

We must accept that biosolids are a by-product of human activity, and that biosolids production amounts will increase in tandem with population growth. The quality of land used for farming must be maintained and, ideally, improved to satisfy a key national need – fresh, high-quality food at reasonable prices. Biosolids that are reused and recycled for land reclamation, landscaping, and agricultural purposes may eventually seem practical.

California – City of Los Angeles: Bureau of Sanitation

BACKGROUND

The City of Los Angeles: Bureau of Sanitation (City) is responsible for operating and maintaining one of the world's largest wastewater collection and treatment systems. Over 6,500 miles of sewers serve more than four million residential and business customers in Los Angeles and 29 contracting cities and agencies. These sewers are connected to the City's four wastewater and water reclamation plants that process an average of 550 million gallons of wastewater each day of the year. The City generates approximately 650 wet tons per day (wtpd) of dewatered digested biosolids: approximately 600 wtpd at the Hyperion Treatment Plant (HTP) and 50 wtpd at the Terminal Island Wastewater Reclamation Plant (TIWRP). The sewers and treatment systems are continually upgraded to ensure that the health of the public and our environment are protected. Strict quality control procedures and regulatory compliance with federal and local laws are followed for the production and beneficial recycling of biosolids.

Biosolids environmental management system

The City embarked on a voluntary program called the Biosolids Environmental Management System (EMS). The EMS is a program developed by the National Biosolids Partnership (NBP) to improve the quality of biosolids management programs nationwide and to promote public acceptance of recycling biosolids and other modern management practices. The EMS addresses the management aspects of the City's biosolids program and encourages public participation and communication. In September 2003, the City's EMS program was verified by an independent third party auditor and became the second agency in the nation to be admitted to the NBP EMS program. The certification was retained in 2004 and 2006 after an independent auditor verified the program. The City received the NBP EMS platinum certification status in October 2006. This status designates that the City has maintained the highest standards possible for biosolids management and environmental stewardship.

HYPERION TREATMENT PLANT

The Hyperion Treatment Plant is the City's oldest and largest wastewater treatment facility. The plant has been operating since 1894 and has been expanded and improved numerous times over the last century. Currently, the plant treats approximately 350-450 million gallons per day of raw sewage.

From 1894 until 1925, raw sewage was discharged into near-shore ocean waters. To address basic public health and sanitation needs, the City built and began operating a simple screening plant in 1925.

In 1950, Hyperion had a full secondary as well as primary treatment facilities, air quality control and odor management systems. Sludge drying equipment produced a recyclable soil amendment for many years. The treatment plant was among the first in the world to capitalize upon the energy value of the sludge it treated; anaerobic digesters have yielded a fuel gas similar to natural gas for over forty years.

In the 1980's, the City kept pace with the developing industry of energy recovery from renewable resources. An innovative drying and combustion system called the Hyperion Energy Recovery System (HERS) used the Carver-Greenfield process and a fluidized-bed gasifier to convert sludge solids to fuel. This process was added to extract all possible energy from sludge organics. However, this state-of-the-art option was unsuccessful and is no longer running today.

Currently, wastewater treatment at Hyperion Treatment Plant consists of screening of large bulky items, grit removal, primary treatment by sedimentation, intermediate pumping stations, pure oxygen reactors, clarifying tanks, waste activated sludge centrifuges, anaerobic digestion, and centrifuge dewatering.

The biosolids produced at Hyperion were disposed in the ocean and in landfills until 1989, when the City started an extensive beneficial reuse program, which continues today. The City received national awards from the U.S. EPA for rapid conversion from disposal to beneficial use of biosolids in 1989 and outstanding 100% beneficial reuse in 1994. In 2003, special recognition and awards were received from the Association of Metropolitan Sewerage Agencies (AMSA) and U.S. EPA for the City's Exceptional Quality Biosolids Program.

TERMINAL ISLAND WASTEWATER RECLAMATION PLANT

The Terminal Island Wastewater Reclamation Plant is located 20 miles south of downtown Los Angeles in San Pedro. The plant treats wastewater from over 130,000 people and 100 businesses in the heavily industrialized Los Angeles Harbor area, including the communities of Wilmington, San Pedro, and a portion of Harbor City.

The plant has recently become the third Los Angeles wastewater treatment plant to produce reclaimed water and one of the few plants in the country that produce water using reverse osmosis. This exceptional quality water will soon be used as a potable water replacement in Harbor area industrial applications and as a barrier against seawater intrusion. The plant also produces biosolids and biogas for beneficial reuse.

The Terminal Island Wastewater Reclamation Plant was built in 1935 and has undergone numerous improvements and upgrades in 1977, 1981, and 1997 to comply with new State and federal clean water regulations to improve protection of public health and the environment.

In 1977 the treatment plant upgraded its facilities so that all wastewater could be treated to the secondary level. This upgrade also included this country's first egg-shaped digesters for processing sludge to beneficial biosolids. In 1997 the plant was upgraded to the tertiary treatment level, allowing the plant to distribute reclaimed water for reuse in the Harbor area. These were major steps toward improving the health of the Harbor and ocean environments.

SELECTION OF DISPOSAL PRACTICE

The City generated a total of approximately 255,500 wet tons or 77,400 dry tons of biosolids in 2007. Approximately 91 percent of the City's biosolids are loaded onto trucks at the plants and transported to the 4,688 acres City-owned Green Acres Farm in Kern County, CA, where the Class A, Exceptional Quality biosolids are recycled as a fertilizer and soil amendment. Corn, wheat, Milo, Sudan grass, and alfalfa are grown on the farm as non-food crops. At present, approximately 8 percent of the City's biosolids are transported to a windrow composting facility in Ontario, CA, through a contract with Solid Solutions LLC. The resulting compost is then beneficially recycled in various garden and agricultural settings. The remaining biosolids are composted at a City-owned composting facility at Griffith Park. The Griffith Park Composting Facility mixes green waste and zoo manure from the Los Angeles Zoo to produce compost. In addition, the City is currently close to the initiation of the Terminal Island Renewable Energy Project (TIRE). TIRE allows the City, over a five-year period, to drill three wells — one injection and two to monitor the effectiveness of the project – pumping up to the equivalent flow of 400 tons of biosolids per day to evaluate potential benefits of using slurry-fracture injection technology. This technology allows the City to convert biosolids into a renewable energy source.

ECONOMIC INFORMATION

The costs of operations based on FY 2006-2007 budgets and costs are as follows:

- Typical proportion of sewerage operation costs attributable to sludge are approximately 21% Capital and 21% Operations & Maintenance (O&M).
- The Department of Public Works: Bureau of Sanitation and the Department of Water and Power have a contract to convert Hyperion Treatment Plant's methane gas produced

at its anaerobic digesters into power. Currently, Hyperion demands approximately 20 megawatts and the following briefly describes the rates.

- The first 17 megawatts: $0.01054 per kilowatt hour
- Beyond 17 megawatts: $0.0636 per kilowatt hour
- The average cost of diesel fuel in the State of California was $3.32 per gallon.
- The City does not directly bill sewer users because operations are financed from City general revenues.

GRIFFITH PARK COMPOST

Currently, the Bureau of Sanitation (HTP and SRCRD), in conjunction with the Department of Recreation and Parks (R&P), operates a composting facility at Griffith Park. The facility produces 20 to 30 tons of compost daily by recycling Hyperion Treatment Plant biosolids, yard trimmings generated within the park and manure from the L.A. Zoo. About 50% of product usually is sold to a contractor and the remaining 50% is donated to the R&P, other City agencies, or nonprofit educational organizations.

A uniform mix of 15 tons of biosolids, 50 cubic yards of green trimmings, 20 cubic yards of zoo manure, and 10 cubic yards of coarse screened reject per pile provides an ideal Carbon to Nitrogen ratio of 30:1. If there is a shortage of zoo manure the necessary volume can be replaced with green trimmings and/or screened reject. Additionally, 10 cubic yards of coarse screened reject per pile is used as cover.

Yard trimming from Griffith Park and manure from the L.A. Zoo is delivered to the site to be loaded into a mobile mixer unit with a skiploader. These materials are blended in the mixer with biosolids from Hyperion Treatment Plant. A conveyor then transfers the mixture into a designated area called a cell. New cells cover finished compost using a skiploader. Compressors blow air through cells in various stages of composting. Adjacent cells of finished compost act as biofilters for the exhaust from the aerated cells. Cell area is provided for composting detention times of 28 days, after which the material is relocated with the skiploader to adjacent area for additional 28 days of curing. The finished compost is screened and stored in a separate location.

The finished compost product, TOPGRO®, is sold to a private contractor and donated to the R&P, other City's departments, and nonprofit educational organizations. The product is not sold or given away to general public. Interested parties call the facility to arrange for pick up of the product. The operator loads the product onto a truck and records amount in cubic yards in the daily log.

LAND APPLICATION AT GREEN ACRES FARM

In August 2000, the City purchased a 4,688-acre farm named Green Acres in Kern County to ensure a reliable place to recycle the City's biosolids from the wastewater treatment plants. The biosolids are used as a soil conditioner and fertilizer to help promote growth on sites where chemical fertilizers and other amendments would otherwise have to be used to produce crops. Farm activities produce non-food chain crops such as wheat, corn, Milo, alfalfa, and Sudan grass as feedstock for the local dairies.

The biosolids are applied in bulk and managed as a Class A, EQ product in compliance with all federal, state, and local regulations. As a best management practice tool the City looks to, as guidance, the California Water Environment Association (CWEA) Manual of Good Practice for Agriculture Land Application of Biosolids. The contractor, Responsible Biosolids Management Inc. (RBM), consults the manual as a guide for land applying biosolids at the City farm as part of the contract agreement with the City. At this time, the City contracts with RBM for the loading, transporting, and beneficial use of biosolids at the City-owned Green Acres Farm in Kern County. RBM land applies biosolids with conventional agricultural equipment such as manure spreaders, tractors, and front-end loaders. The biosolids are typically incorporated into the soil by means of plowing or disking. The City typically incorporates its biosolids into the soil within 30 minutes after it is off-loaded at the farm. The contract, set to expire in September 2010, specifies a minimum daily tonnage of 548 wtpd. The biosolids provide soil-amendment and fertilizer properties to enrich the soil.

Recently, the City has faced and overcome certain legal and regulatory challenges fueled by certain misperceptions regarding the safety of and benefits of biosolids recycling. Due to pressure from certain activists, a few of counties are considering implementation of regulations restricting or banning the land application of biosolids. In June 6, 2006, Kern County voters passed a ballot initiative that banned land application of all biosolids or biosolids products in the unincorporated areas of Kern County. This created uncertainty in biosolids management at Green Acres Farm and compelled new flexibility in management strategies and goals for the City's biosolids management program.

In response to the ban, the City of Los Angeles, along with other affected Southern California counties and agencies, successfully prosecuted a lawsuit in federal court in August 2006 challenging Kern County's ban on the land application of biosolids. In August 2007, the federal court invalidated the Kern ban, holding it in violation of the United States Constitution and preempted by state law. The court's prior order granting the City a preliminary injunction against the ban and allowing land application to continue found that "[t]he public is best served by disposing of sewage sludge in the safest and least expensive manner possible…[T]hat method is land application of Class A EQ biosolids at…Green Acres." Kern has appealed the federal court's ruling to the Ninth Circuit.

Solid Solutions, LLC.

Due to the uncertainties in biosolids management at Green Acres Farm and the City's commitment to maintaining 100 percent beneficial use of biosolids at its wastewater treatment plants, the City signed a contract agreement with Solid Solutions, LLC (Solid Solutions) to allow for flexibility in taking the City's biosolids to Arizona for land application. The contract term is for three years and started on October 2007 with a minimum tonnage of 51 wet tons per day. Solid Solutions has the option to land apply and compost in California and Arizona. At present, biosolids are transported to a windrow composting facility in Ontario, CA. Solid Solutions is responsible for land application, hauling, and associated farming activities as it is included in the cost.

TERMINAL ISLAND RENEWABLE ENERGY

The TIRE project is a pioneering and groundbreaking green initiative led by the City of Los Angeles with Terralog Technologies and in collaboration with the US Environmental Protection Agency. TIRE allows the City, over a five-year period, to drill three wells — one injection and two to monitor the effectiveness of the project – pumping up to the equivalent flow of 400 tons of biosolids per day to evaluate potential benefits of using slurry-fracture injection technology. The demonstration project will adapt existing petroleum industry technology in an innovative way to convert the constant and growing supply of biosolids into a new source of alternative energy that helps to reduce the greenhouse gases that contribute to climate change. The demonstration project will include extensive field monitoring and sampling from the offset monitoring wells to quantify slurry placement, biodegradation rates, carbon dioxide and methane separation, carbon dioxide sequestration and saturation in formation brine, and free gas migration and production. The potential benefits of this experiment include safety of disposal, generation of methane for future energy use, permanent carbon dioxide sequestration, enhanced treatment and sterilization of biosolids, reduction of long distance truck traffic, reduction of greenhouse gas emissions to the atmosphere, enhancement of thermal treatment and sterilization, and improvement of groundwater protection.

LANDFILL

The City's biosolids policy states that the City is committed to maintaining 100 percent beneficial use of biosolids produced at its wastewater treatment plants. Therefore, the City is committed to diverting its biosolids from landfills unless there is a relatively rare occurrence of events that may lead to the need to dispose biosolids in landfills.

OTHER OPTIONS

Incineration is not part of the City's biosolids management program at this time. Furthermore, the City does not apply its biosolids in forests/woodland, on conservation and non-sporting recreation land, or for land reclamation.

GENERAL AGRICULTURAL SERVICE PRACTICE

The City is committed to complying with all applicable federal, state, and local laws and regulations. The biosolids produced meet or exceed the Class A "Exceptional Quality" (EQ) biosolids standard as defined by the U.S. Environmental Protection Agency (EPA) in the Code of Federal Regulations (CFR), 40 CFR 503 ("Part 503"). In addition, the City has complied with the Part 503 rule since it was promulgated in 1993 and requires its land appliers to use as guidance the CWEA Manual of Good Practice for Agricultural Land Application of Biosolids.

The following are the average values for the pollutants regulated by the EPA for the wet cake at Hyperion Treatment Plant and Terminal Island Wastewater Reclamation Plant.

Pollutant	Ceiling Concentration (mg/kg)	High Quality Limit (mg/kg)	Wet Cake at Hyperion Treatment Plant (mg/kg)	Wet Cake at Terminal Island Reclamation Plant (mg/kg)
Arsenic	75	41	6.05	11.9
Cadmium	85	39	10.2	4.28
Chromium	—	—	84.0	45.1
Copper	4,300	1,500	1,060	352
Lead	840	300	38.5	43.5
Mercury	57	17	1.91	1.78
Molybdenum	75	—	17.8	29.1
Nickel	420	420	50.8	42.8
Selenium	100	100	14.5	67.0
Zinc	7,500	2,800	1,180	1,020

The biosolids applied at Green Acres are monitored and tested by a California Department of Health Services certified laboratory to ensure that metal concentrations are low and pathogens are non-detectable. California Title 22, organics such as polychlorinated biphenyls (PCBs) and dioxins are also monitored. The tests results show that City's levels for PCBs and dioxins are at non-detectable levels.

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Colorado

BACKGROUND

The Metro Wastewater Reclamation District (Metro District) is a regional government formed under Colorado law in 1961 to provide wastewater transmission and treatment services to member municipalities and special connectors in the Denver metropolitan area. There are currently 57 local governments serving 1.5 million people for whom the Metro District provides wholesale wastewater treatment. The 380-square mile service area includes Denver, Arvada, Aurora, Lakewood, Thornton, and Westminster. The Robert W. Hite Treatment Facility (RWHTF) began operating in 1966 and currently treats approximately 140 million gallons per day (MGD) of wastewater. The Facility is rated at 227 MGD. Approximately 97% of the wastewater comes from households. The remaining three percent is discharged from industrial sources and is tightly controlled under the Metro District's Industrial Waste Pretreatment Program. The Metro District discharges the treated water into the South Platte River, where it provides about 85% of the flow for nine months of the year.

The Metro District employs two systems to reduce the amount of pollutants discharged into the wastewater interceptor sewer system. The first system is the Industrial Waste Pretreatment Program, which focuses on treating industrial waste at the source before its release into the Metro District's interceptor sewer system. The second system includes the RWHTF treatment processes that target the removal of pollutants, metals, pathogens, and nutrients such as nitrogen.

The solids that are removed during the treatment process, about 80 dry tons per day, meet federal and state regulatory standards for beneficial use. Only solids that meet these standards can be identified as biosolids, such as the Metro District's METROGRO® Cake and Compost products. METROGRO® Cake is anaerobically digested solid material. Anaerobic digestion further breaks down the solids and destroys pathogens. The digested solids are then processed through high-solids centrifuges to remove water, leaving a mixture that is fairly homogeneous averaging 23% solids and having the consistency of thick cake batter. Although METROGRO® Cake is used primarily in agriculture on farmland; it can also be beneficially used on rangeland, in forests, and for land reclamation projects.

METROGRO® Compost is a product generated by mixing METROGRO® Cake and wood fiber or yard waste. The mixture is processed using aerated static piles to meet more restrictive federal and state Class A biosolids criteria for pathogen reduction. Following screening, the compost is ready for unrestricted distribution to consumers in bagged or bulk form. Both METROGRO® Cake and METROGRO® Compost are registered fertilizers with the Colorado Department of Agriculture.

The RWHTF's solids processing train includes 12 conventional mesophillic anaerobic digesters. The digesters process combined primary and waste-activated sludge and can operate in either a two-phase or conventional high-rate strategy. The digesters produce methane-rich gas in excess of 3 million cubic feet per day. Since 1985, the Metro District has beneficially used the gas in its cogeneration facility to produce electricity and industrial grade hot water. The cogeneration facility produces an average of four megawatts of electricity per day, provides process heating for the 12 digesters, building heat for some of the buildings on the RWHTF, and biosolids preheating prior to digestion.

The table below describes the average cogeneration energy production and usage:

	Average Cogen Net Energy Production (kWh)	Average % of Total Facility Electrical Energy Consumption	Average Cogen Waste Heat Generation MMBtu/hr
2006	2,283,253	39	13.6
2007	2,592,107	37	13.2

SELECTION OF DISPOSAL PRACTICE

The Metro District produced 27,719 dry tons of biosolids in 2007. Under a policy first adopted by the Metro District's Board of Directors in 1978 and modified in 2004, the Metro District seeks to beneficially use all of the biosolids it produces. Continuing with its traditional practice, the majority of the biosolids were land applied to agricultural land as METROGRO® Cake. A much smaller portion was further processed in the onsite 17-acre, under-roof compost operation. In addition, some of the biosolids produced were taken to a private contract composter. Record snow storms in the winter of 2007 prevented biosolids land application for 60 days, causing the Metro District staff to use a landfill as a last resort. The table below shows a summary of the Metro District's biosolids management options for 2007:

Option	Agricultural Land Application	Compost	Private Contract Composter	Landfill
Dry Tons	21,670	2,460	2,063	1,526
% of Annual Production	78.2	8.9	7.4	4.8

AGRICULTURAL LAND APPLICATION

The Metro District owns the transportation fleet used to haul biosolids and all of the necessary land application equipment. The Metro District employs 17 Field Operators who run the biosolids distribution operation. In addition, the Metro District employs nine Field Mechanics who service all of the equipment needed for land application as well as the entire Metro District fleet. To manage the daily (avg. 18 truckloads) biosolids operation, there are 18 road tractors, 18 trailers (8 live bottom, 8 end dump, 2 belly dump), 4 biosolids spreaders, 4 farm tractors and 18 implements. Farm tractors and implements are used when incorporation of biosolids is required by regulation or requested by the farmer.

Each land application site has been permitted by the Colorado Department of Public Health and Environment CDPHE). The Metro District had 330 permitted land application sites in 2007, totaling 95,526 acres. Where applicable, the sites are also permitted by their respective county. Eighty-six percent of these acres are dryland and typically are farmed in a wheat-fallow rotation so only half of those acres are available each year for biosolids application. The remaining 14% are irrigated sites. Each of the irrigated sites is available (soil analysis permitting) for biosolids application each year or once per cropping cycle. Biosolids were applied to 11,487 acres by the Metro District in 2007, with 69% being dryland and 31% irrigated.

METROGRO FARM

In 1993 and 1995 the Metro District purchased farmland approximately 70 miles east of the Facility near Deer Trail, Colorado, in Arapahoe and Elbert Counties. The 52,000 contiguous acres (80 square miles) property is referred to as the METROGRO Farm (the Farm). The Farm consists of three properties: North, Central, and South; the Farm in its entirety is a dryland operation. Because METROGRO® Cake meets exceptional quality standards as set forth by the United States Environmental Protection Agency (EPA) and CDPHE, incorporation is not a requirement. This is conducive to the minimal-till farming operations practiced on the Farm. In 2007, 2,354 dry tons of METROGRO® Cake was applied to the Farm. The South property is the largest of the three and received 69% of the Farm-applied biosolids. Although Metro District staff applies biosolids at the Farm, a tenant farmer is responsible for farming activities and works under the terms of a lease agreement.

PRIVATE FARM SITES

The Metro District also applies biosolids to privately owned farmland in several counties along the Colorado Front Range, such as Adams, Arapahoe, Morgan, Washington, and Weld.

By having the METROGRO Farm and maintaining application sites owned by private farmers, the Metro District's biosolids land application operation has the diversity it needs to accommodate various cropping cycles and most inclement weather events to strive for 100% beneficial use.

COMPOST OPERATION

During 2007, the Metro District composted 8.9% of its annual biosolids production. During inclement weather when major roads are closed and/or poor field conditions exist, biosolids are diverted to the composting facility located at the RWHTF. The finished Class A biosolids METROGRO® Compost meets the exceptional quality requirements set forth by the EPA and CDPHE and is sold in bulk or bags without restriction. This product is widely used by the general public in the Denver metro area for turf and garden fertilizer and by professional landscapers for parks and golf courses. Together with some carryover from 2006 inventory, the Metro District distributed 2,206 dry tons and 5,031 bags of METROGRO® Compost in 2007, creating $79,797 in total revenue.

Marketing of METROGRO® products is done primarily through word-of-mouth. The Metro District does not expend money for traditional, paid, mass-media advertising for METROGRO® products, but it does spend about $10,000 a year to promote the products. METROGRO® product promotion takes place primarily through one-on-one, face-to-face encounters with potential customers during events such as the Colorado Garden and Home Show, the People's Fair in Denver, and the Colorado Farm Show, which is one of the largest shows of its kind in the West that talks directly to farmers. The Metro District also provides product information to the news media and on an external website as well as through facility tours for affinity groups such as the Master Gardeners (who are supported by the Colorado State University Agricultural Extension Service) and others who have shown a particular interest in the Metro District's agriculture-related activities and products. A strong demand exists in the Denver metro area for METROGRO® Compost. In addition, there is an extensive waiting list for farmers to become part of the Metro District's biosolids management program.

PRIVATE COMPOST COMPANY

The need for an alternative management option, the timing of when it is needed, and the duration of the event that would result in the need are all variable. Consequently, A1 Organics (a privately owned composter) and Metro District staff negotiated a contract that calls for the Metro District to deliver a guaranteed minimum of eight truckloads of biosolids to A1 Organics every week. In return, A1 Organics can guarantee that when the District does need it as a biosolids outlet during inclement weather, emergency conditions or operational peak demand times, it will accommodate the Metro District's full biosolids production. Implementing this option also allowed the Metro District to be prepared for long-term impacts of reduced on-site composting capacity because of the expansion of the wastewater treatment processes.

A1 Organics is one of two private compost companies in the State of Colorado permitted to compost biosolids, and it has the physical and operational capacity, resources, and knowledge to be an alternative for the Metro District's composting operations. A1 Organics' biosolids composting process meets the intent of the Metro District's Environmental Management System for Biosolids program and Biosolids Reuse Policy that states the District will beneficially use biosolids. A1 Organics composts the biosolids into a Class A product and markets it under one of its own compost trade names.

BIOSOLIDS SHORT-TERM STORAGE

On rare occasions when the front range of Colorado experiences severe weather that closes major highways to the various application sites, the Metro District has a four-day biosolids storage capacity at the RWHTF. Cake Towers (silos) where biosolids are stored until loaded into the transport trucks daily can hold two days' biosolids production. In addition, an area in the composting facility is designated to store approximately two days worth of the facility's biosolids production.

In late 2005 and early 2006, Metro District staff constructed, and now maintains, three 80- by 120-foot containment areas at the METROGRO Farm for biosolids storage. These containment areas were designed to hold approximately 12 days' biosolids production. These short-term storage areas are primarily used when inclement weather causes poor field conditions and land application of biosolids is undesirable.

Colorado Biosolids Regulation #64 allows for 14-day short-term storage. When any of these short-term storage areas is used, the Metro District staff manages the material through the first-in, first-out (FIFO) system. The oldest material is distributed first to ensure regulation compliance.

LANDFILL

On very rare occasions, and as a last resort when extended precipitation events have occurred in Colorado and the composting facility, private compost company and the short-term biosolids storage options are at capacity, biosolids can be diverted to a landfill.

In addition, if the RWHTF's processes experienced an upset condition and could not meet Class B biosolids criteria, material could be diverted to the Metro District's composing facility and/or the private composting company and processed into Class A biosolids. If these two options are unavailable at the time, material would be diverted to the landfill until the plant could resume normal operation and demonstrate Class B compliance. The Metro District maintains permits at four local landfill facilities to accommodate these situations.

INCINERATION

The Metro District does not practice biosolids incineration. However, in long-term facility studies, thermal drying of biosolids is a viable option for the Metro District in the future. Thermal drying uses heat to dry the wet biosolids into a Class A product that can be distributed without restriction.

The following table illustrates the 2007 average values for the pollutants regulated by the EPA CFR Part 503 for both METROGRO® Cake and Compost (mg/kg dry weight basis):

Pollutant	Ceiling Concentration	Exceptional Quality (EQ) Limit	METROGRO® Cake	METROGRO® Compost
Arsenic	75	41	2.6	3.9
Cadmium	85	39	2	2
Copper	4300	1500	670	699
Lead	840	300	39	37
Mercury	57	17	1.3	1.4
Molybdenum	75	—	20	24
Nickel	420	420	16	16
Selenium	100	100	14.8	12.2
Zinc	7500	2800	714	743

ECONOMIC INFORMATION

The Metro District treats sewage discharged from its 57 Connectors via an interceptor system that connects them to the RWHTF. Each Connector is assessed Annual Charges for Service based on five charge parameters: Flow, Biochemical Oxygen Demand (BOD), Suspended Solids (SS), Total Kjeldahl Nitrogen (TKN), and a Customer Equivalent Connection Unit (CECU), which represents the amount of metering and sampling done. The CECU charge is higher for larger Connectors because metering and sampling are performed more often than for the smaller Connectors.

A computer model calculates a unit charge for each of these five charge parameters based on the budget for the year and the amount of each of the charge parameters anticipated. For 2008, the unit charges are:

- Flow: $495.50 /Million Gallons
- BOD: $465.08/Ton
- SS: $356.29/Ton
- TKN: $674.57/Ton
- CECU: $20,979
- 264 gallons (1,000 liters) of diesel fuel: $654.72

SPECIAL PROJECTS FOR RECLAMATION

METROGRO Farm

When the METROGRO Farm was purchased, there were areas where soil erosion was a major concern. The Metro District held several discussions with local conservation districts, the EPA, and the CDPHE to decide what appropriate action should be taken with the erosion areas on the Farm. A decision was made to reclaim these areas, take them out of crop production, and return them to grass. The Metro District then applied for a one-time variance for these areas to apply biosolids at land reclamation rates. The request was approved by the CDPHE. The erosion areas received biosolids application at five times the regular agronomic rate. Oats and grass seed were planted and the erosion areas were taken out of crop production.

Buffalo Creek, Colorado Fire

The Buffalo Creek Fire in May 1996 burned 11,876 acres of ponderosa pine forest. In July 1996, runoff from the burned area caused flooding that resulted in loss of life and property, erosion of valuable topsoil, and substantial water quality problems. Burned areas continue to deteriorate until stabilized with vegetation. Using biosolids for ecosystem restoration is not uncommon; however, in 1996 there was no documented research using biosolids for the restoration of burned areas. In cooperation with the EPA, the CDPHE, the USDA Forest Service, Colorado State University, and the Littleton/Englewood Wastewater Treatment Plant, the Metro District participated in the reclamation project for portions of the burned area. The Metro District transported and applied biosolids. Metro District staff also assisted in preparing the biosolids application area for seed and the actual planting of the seed. The original study concluded there was a short-term increase in vegetation productivity and cover establishment resulting from the use of biosolids to aid in wildfire rehabilitation.

In 2008, Colorado State University submitted a proposal to the Metro District for a research project looking at the long-term vegetation response to biosolids application following the forest fire. The project, now in progress, will evaluate plant community composition, plant canopy cover related to species, tree seedlings, soil carbon and nitrogen, compare data with that of other studies around the country, and validate the findings of the first study.

Upper Arkansas River Fluvial Tailings Reclamation Project Leadville, Colorado

Mining and smelting of metal ores in the Leadville, Colorado, area generated large quantities of waste materials including tailings more than a century ago. Metal concentrations in tailings are a function of the efficiency of the refining operations. In Leadville, tailing piles from historical mining operations located in the California Gulch had washed down the Arkansas River during high-intensity storms. The tailings had high concentrations of zinc, lead, manganese, and a high acid-generating potential. Tailing deposits along the 11-mile section of the upper Arkansas River left areas barren of vegetation. Although biosolids are generally applied to farmland to meet nitrogen needs of a crop, in this case, biosolids were applied to create a new surface soil horizon as well as to chemically alter the properties of the underlying horizon. In cooperation with EPA and the Lake County Conservation District, the Metro District transported and applied biosolids as defined in the proposed plan in 1998.

Colorado State University has conducted research on the biosolids-applied area since the reclamation project began. Research includes: site investigations to evaluate native and planted vegetation conditions, physical and chemical soil properties, soil microbial populations, molybdenum uptake and availability, and water quality; and a digestibility and retention study of molybdenum in forage harvested from the tailing ponds in crossbred beef cattle. A final report detailing information from 1998 to 2008 is expected in the summer of 2008.

SOIL INFORMATION

Typical Colorado soils are favorable for repeat biosolids applications. Phosphorus levels are naturally adequate in the majority of Colorado soils. Characteristic pH of the soils in Colorado has a value ranging from 7.0 – 8.0, so they are rather neutral. With Colorado Biosolids Regulation #64 and average METROGRO® biosolids metal concentrations, copper is the limiting nutrient for land application of biosolids. It would take an average of 525 years of consecutive biosolids application at the rate of 1-2 dry tons per acre to reach the ceiling limit for copper, and land application would then be discontinued on any given site.

CROP INFORMATION

Eastern Colorado is a semi-arid climate, and water for crops comes from rain and snow melt. The proper combination of fertilizer with the amount and timing of precipitation can significantly increase yields. Common crops grown are wheat, corn, oats, sunflowers, milo, millet, and forage. Pastures are also utilized for biosolids application. Soil samples are taken before biosolids are applied to ensure the proper amount of nitrogen for the desired crop yield is met. Typical application rates vary from 1-1.5 dry ton/acre for dryland crops. Irrigated crop application rates vary from 8-10 dry ton/acre.

REGULATION

The Metro District complies with the EPA CFR Part 503 Biosolids Regulation and the Colorado Biosolids Regulation #64, which has additional requirements beyond those contained in the EPA 503. Some additional requirements in Colorado Biosolids Regulation #64 that are not required by the EPA 503 are:

- Weekly notification of active biosolids application sites to local health authority officials
- Use of the Plant Available Nitrogen agronomic application calculation
- Soil analysis using extractable metal concentrations, and
- Soil pH must be above 6.0 standard units

As Colorado is not yet an EPA-delegated biosolids program, the Metro District also complies with another set of requirements. EPA Region VIII issued a *General Permit for Facilities/Operations that Generate, Treat, and /or Use/Dispose of Sewage Sludge by Means of Land Application, Landfill, and Surface Disposal under the National Pollutant Discharge Elimination System*. This General Permit does not replace current Colorado biosolids regulation, but adds an additional layer of federal biosolids land application program requirements. Three additional requirements of the General Permit are:

- Provide an overall Biosolids Management Plan each year
- Provide information on any current year crop failure, and
- Deep soil (five feet) monitoring for irrigated land application sites once every five years

In addition to the federal and state biosolids regulations, several counties also have biosolids regulations in place that require a permitting process. Some of the additional requirements for obtaining county permits are:

- Contacting adjacent neighbors to the land application sites
- Posting notification at land application sites
- Attending public hearings regarding land application sites, and
- Maintaining/repairing county roads around the land application sites

The Metro District also falls under a fee structure associated with the Colorado Department of Agriculture. Because METROGRO® products are registered as a fertilizer/soil amendment; annual fees are assessed based on the amount of product sold to consumers.

All federal, state and local permits must be obtained prior to the application of biosolids. Fees for these various biosolids related permits and registrations cost the Metro District approximately $130,000 per year.

CURRENT BIOSOLIDS MANAGEMENT PROGRAM CONCERNS

Drought conditions

Drought continues to be a cyclical concern. Because of drought conditions in Colorado over the past several years, crop yields have been less than desirable, and that resulted in minimal nutrient uptake by the growing crop. Many of the fields on the METROGRO Farm have had too much residual nitrogen in the soil to warrant applying any additional fertilizer. This resulted in a Metro District staff decision to give the METROGRO Farm a "rest." This has required Metro District staff to aggressively pursue more private farm sites while continuing to apply only a small percentage of biosolids to the METROGRO Farm. When rainfall levels return to normal, the crop nutrient uptake will increase and yields will improve, allowing for additional available fields on the METROGRO Farm for land application.

Drought conditions have also impacted private farmers with dryland cropping systems. Similar to the residual soil nutrient situation on the METROGRO Farm, soil sample results have been unpredictable and, in some situations, private farm fields could not receive biosolids application.

Agronomic application rate calculation changes

Colorado Biosolids Regulation #64 now includes a policy that outlines a standard method for calculating agronomic application rates for all Colorado biosolids applicators. The Plant Available Nitrogen (PAN) calculation method became a requirement in 2007. The Metro District calculated its agronomic application rates using Total Kjeldahl Nitrogen (TKN) prior to the mandated PAN method. In June 2006, the Metro District began migrating to the PAN method in anticipation of the mandated requirement.

The initial effect on the Metro District's biosolids program was an average reduction of 30 percent in total biosolids applied to any site. With the Metro District producing more biosolids each day, this created a need for additional land application sites to handle the daily biosolids production. Focus was placed upon gaining more irrigated acres because these acres are available each cropping season and often require a heavier agronomic loading rate than dryland acres.

Since the Metro District had been feeling the effects of continued drought conditions, additional land application sites were already in the permit process, so the elevated pressure from the mandated PAN calculation method was not as consequential as it could have been.

Urban development

Continuous, extensive growth and urbanization along the Front Range of Colorado has caused a decline in the availability of private farmland for land application. Colorado has lost 3 million farmland acres since 1992, and predictions are that the northern half of the state will lose an additional 225,000 acres by 2030. This means the Metro District will be forced to haul biosolids greater distances for suitable biosolids application sites. Hauling biosolids greater distances will result in increasing transportation costs, reducing reliability as well as creating more potential for vehicle accidents. Urbanization also brings homeowners in closer contact with the Metro District's land application program, increasing the possibility of complaints to local regulatory officials. Such complaints could trigger more restrictions on beneficial practices at the local level and make land application of Class B biosolids more difficult.

Fuel costs

Rising fuel costs continue to affect transportation and many other related functions, such as manufacturing and delivering vehicle parts. Metro District staff continues to evaluate ways to reduce fuel consumption, such as reducing idling time on vehicles and field equipment during day-to-day operations. Compost deliveries to smaller, residential customers were also suspended indefinitely, reducing the amount of travel time in the metro Denver area, where traffic jams are frequent.

The Metro District is also currently converting its entire fleet of vehicles into a green fleet. Hybrid vehicles have been purchased to replace gas vehicles. When vehicles are due for replacement, a job function analysis is performed to determine whether a smaller vehicle would be sufficient. The Metro District has been able to reduce the number of four-wheel drive vehicles in its fleet. Also, an evaluation of using biodiesel in the biosolids transport units is being done using two of the 18 road tractors. The Metro District is considering the use of biodiesel as an alternate fuel source for its road tractors in the future and is looking to make budget adjustments to accommodate such a program. The Metro District wishes to manage and operate its fleet in a manner that is energy efficient and minimizes emissions.

ENVIRONMENTAL MANAGEMENT SYSTEM FOR BIOSOLIDS

In July 2005, the Metro District became the eighth wastewater agency in the United States to receive certification for its Environmental Management System (EMS) for Biosolids program. The EMS documents the Metro District's overall biosolids management program. (mg/kg dry weight basis). The EMS ensures that biosolids are processed appropriately, safely, and in accordance with all applicable regulations. The EMS also provides a platform to make certain management of the biosolids program is efficient and environmentally sound.

Through EMS, the Metro District is committed to beneficially recycle biosolids and in all cases take steps necessary to protect public health and the environment, be sensitive and responsive to public concern, and strive for continual improvement.

Delaware – Kent County Regional Wastewater Treatment Facility (KCRWTF)

BACKGROUND

Kent County is the middle of Delaware's three counties. It is the smallest of the three, having a population of approximately 140,000. The major city in the county, Dover (which is the second largest city in Delaware), also serves as the state capital. Kent County is bounded to the north by New Castle County, to the south by Sussex County, to the west by Maryland, and to the east by the Delaware River and Delaware Bay. The county is a mix of industry, regional commercial banking and retail, farming, and numerous bedroom communities for nearby Wilmington, DE and Philadelphia, PA. Major activity areas within the county include a state park, Dover Air Force Base, Dover Downs, the Delaware State Fairgrounds complex, and several significant industries that discharge into the county wastewater system.

Kent County is a commissioner-based, county manager-operated government. Included within the Public Works Department are the wastewater treatment plant that treats most of the wastewater in the county, over sixty pump stations and nearly 100 miles of gravity sewer and force main, and management of County-owned buildings. The wastewater that enters the Kent County regional system comes from five municipal contract users and seven significant industrial users. The wastewater treatment facility is designed to provide secondary treatment with a design capacity of 16.3 MGD. The City of Harrington operates a separate 0.75 MGD advanced wastewater treatment facility that discharges upstream of the County's discharge. Kent County currently treats the biosolids from the Harrington facility, and will shortly be contracted to land apply the City of Harrington's wastewater on County-owned property.

The facility was the first in the US to be certified to the ISO 14001, OHSAS 18001, and National Biosolids Partnership's EMS standards. It recently won the US EPA's National Clean Water Act Recognition Award for Operations and Maintenance Excellence for Large Advanced Treatment Plants. It is one of only two wastewater facilities participating in the US EPA's National Performance Track program.

WASTEWATER TREATMENT

The original wastewater facility was constructed in 1972. The original facility consisted of aerated lagoons. It has been modified over the past years with the most significant modifications occurring in 1994. At that time, the basins were modified to accommodate the Parkson Biolac® Wave-Ox system. This system is a biological nutrient removal (BNR) system that uses various areas of anoxic conditions to nitrify and denitrify the wastewater. The current wastewater system consists of influent screens, grit chambers, the Biolac system, 4 clarifiers, disinfection using chlorine gas and dechlorination using sulfur dioxide. The final effluent is discharged into a tidal river just upstream of the Delaware Bay.

BIOSOLIDS TREATMENT

Biosolids generated by the wastewater operations are first stored in concrete tanks. They are dewatered on one of two belt filter presses to approximately 20% solids. After dewatering, lime is added to bring the pH of the mixture above 12. The lime amended biosolids are then dried in a series of two indirect dryers to a minimum of 60% solids. The dried biosolids are then stored in a covered area prior to transport to local farms for spreading as a soil amendment. The farmers value it for its lime properties and the available nitrogen and phosphorous content. The biosolids are considered an EPA Class A product.

BIOSOLIDS PRODUCT INFORMATION

The biosolids product, referred to as Kentorganite, is processed at the Kent County Wastewater Facility in Frederica, Delaware. Kentorganite is dewatered local municipal bio-solids mixed with calcium oxide (quick lime). As these two materials are blended, heat is generated that kills pathogens in the bio-solids, and at the same time heat also dries the product, which becomes granular, spreadable material without objectionable odor. Further drying is accomplished by thermal oil cascade type drier. Kentorganite is sold in bulk, by the ton. It meets regulatory requirements set forth by State of Delaware's Department of Agriculture and the Department Of Natural Resources and Environmental Control. The product is analyzed on a monthly basis in the laboratory as well as in field testing.

Kentorganite is effectively used as a liming material for hay crops and field crops such as corn, soybeans wheat, barley, alfalfa, clover, vetch, lespedesa.

Vegetables: processing vegetables, fresh market vegetables that are cooked before eating.

Note: Kentorganite cannot be used on root crops such as potatoes and carrots, or vegetables that are eaten raw. After lime application, there is a twenty four (24) month waiting period before these restricted crops can be grown. Kentorganite cannot be used where tobacco is grown or will be grown.

Soil Texture Determination: Application rates of Kentorganite are directly correlated to the soil texture. Soil texture will be determined by the USDA Soil Conservation Service "Soil Survey", or by soil test explained in routine soil test.

Kentorganite, if properly handled with reasonable care, can greatly enhance the growing conditions of crops. Adequate precaution should be used however, and instructions should be followed explicitly. As with any agriculture input, misuse could result in lower yields as well as potential surface and/or ground water contamination.

- Kentorganite Guaranteed Analysis: Calcium Oxide-20%

Storage, Collection, and Transportation Requirements

Kent County's lime product (Kentorganite) will be stockpiled in the cake storage shed building located on the grounds of the Kent County Wastewater Facility. In addition, all the rainwater run on/runoff from the building and surrounding area will be channeled to a sump and pumped to the headworks of the treatment plant to go through the treatment process.

The lime product will be allowed to accumulate for twenty to thirty days to allow spreading an entire farm without supply interruption. In the case of prolonged inclement weather, the product will be stockpiled in the cake storage building until soil conditions permit land application. Any Kentorganite that has been staged in the field must be covered so as to prevent wetting from rainfall.

Kentorganite must be unloaded/loaded in the field away from slopes, property lines, ditches, tile drains, etc. Extreme care must be taken to avoid the possibility of run on/runoff of surface or groundwater contamination.

Kentorganite can be hauled by either Kent County-owned dump trailers or by privately owned equipment, as long as the load is covered and the tailgate is latched and adjusted to prevent the contents from escaping.

Procedure for farm land application of Kentorganite

1. Farmer calls Ag Ops Dept with request for information of Kentorganite
2. Ag Ops Foreman sends information packet to farmer via mail or hand delivery
3. Farmer reviews information packet and fills out the proper forms and returns them to the Ag Ops Foreman
4. Farmer states they either have a pH of the soil or they need a soil sample taken for the soil pH.
5. If the soil type has the pH below the recommendation in the Kentorganite Packet land application is set up.
6. A time frame for the Kentorganite delivery to the site is agreed upon by the farmer and the Ag Ops Department.
7. The Kentorganite is delivered and piled for land application
8. As time and weather permits the land application task is accomplished by the Ag Ops Dept.

Kentorganite rate recommendation

Table 1. Pounds per acre and pounds per 1,000 square feet required to adjust soil pH to 6.5 based on the Calcium Carbonate Equivalent of 50% our samples run from 45% to 55%

	Loamy sand		Sandy loam		Loam		Silt loam	
pH	**Acre**	**1000 sq ft**	**Acre**	**1000 sq ft**	**Acre**	**1000 sq ft**	**Acre**	**1000 sq ft**
6.5	0	0	0	0	0	0	0	0
6.4	0	0	0	0	0	0	0	0
6.3	0	0	0	0	0	0	0	0
6.2	0	0	2000	50	2000	50	2000	50
6.1	0	0	2000	50	2000	50	2000	50
6.2	2000	50	2000	50	4000	100	4000	100
5.9	2000	50	4000	100	4000	100	4000	100
5.8	2000	50	4000	100	4000	100	4000	100
5.7	4000	100	4000	100	6000	150	6000	150
5.6	4000	100	4000	100	6000	150	6000	150
5.5	4000	100	6000	150	6000	150	6000	150
5.4	4000	100	6000	150	8000	200	8000	200
5.3	4000	100	6000	150	8000	200	8000	200
5.2	6000	150	8000	200	8000	200	10000	250
5.1	6000	150	8000	200	8000	200	10000	250
5.0	6000	150	8000	200	10000	250	10000	250
4.9	8000	200	8000	200	10000	250	12000	300
4.8	8000	200	8000	200	10000	250	12000	300
4.7	8000	200	10000	250	12000	300	14000	350
4.6	8000	200	10000	250	12000	300	14000	350

Table 2. Based on the analysis dated 9-9-94 we are supplying the following nutrients per ton of Kentorganite applied

Total (nitrogen)	42.40 pounds per ton
Phosphorus	13.10 pounds per ton
Potassium	18.44 pounds per ton
Boron	0.80 pounds per ton

- Rates: Delivery $3.75/ ton
  Spreading $2.00/ acre
- No delivery smaller than a trailer load average 20 tons
- Total charges (Net 30 days upon completion of order)
- Tons required per acre X Acres = Total tons ordered

Illinois – Metropolitan Water Reclamation District of Greater Chicago

INTRODUCTION

The Metropolitan Water Reclamation District of Greater Chicago (District) is an independent government and taxing body encompassing approximately 91% of the land area and 98% of the assessed valuation of Cook County, Illinois. The District was originally organized as the Sanitary District of Chicago in 1889 under an act of the Illinois General Assembly, which has been modified from time to time to increase the District's powers and jurisdiction. From 1955 through 1988, the District was called The Metropolitan Sanitary District of Greater Chicago. In order to provide a more accurate perception of the District's current functions and responsibilities, the name was changed, effective January 1, 1989, to the Metropolitan Water Reclamation District of Greater Chicago

The mission of the District is to keep sewage pollution out of Lake Michigan, the area's drinking water supply; to treat sewage to avoid contamination of the Chicago, Des Plaines and Illinois Rivers; and to remove obstructions to navigation from these bodies of water. The District, while it exercises no direct control over wastewater collection and transmission systems maintained by cities, towns and villages in Cook County, does control municipal sewer construction by permits. It also provides the main trunk lines for the collection of wastewater from the location systems together with the treatment and disposal thereof. The District also provides facilities to store, treat and release combined sewage and stormwater run-off within its jurisdiction.

The District serves an equivalent population of 10.1 million people, 5.1 million real people, a commercial and industrial equivalent of 4.5 million people, and a combined sewer overflow equivalent of 0.5 million people. The District serves an area of 872 square miles which includes the City of Chicago and 124 suburban communities. The District's 535 miles of intercepting sewers and force mains range in size from 12 inches to 27 feet in diameter, and are fed by approximately 10,000 local sewer system connections.

The District's Tunnel and Reservoir Plan (TARP) is one of the country's largest public works projects for pollution and flood control. Approximately one hundred and ten (110) miles of tunnels, 9 to 33 feet in diameter and 150 to 300 feet underground, have already been constructed and are in operation.

The District owns and operates one of the world's largest water reclamation plants, in addition to six (6) other plants and 34 pumping stations. The District treats an average of 1.4 billion gallons of wastewater each day. The District's total wastewater treatment capacity is over 2.0 billion gallons per day.

The District is governed by a nine-member Board of Commissioners (the "Board"). The Board is elected at large and serves on a salaried part-time basis. The District's day-to-day operations are managed by the General Superintendent, who reports directly to the Board. The District employs approximately 2,080 employees.

CURRENT AND FUTURE BIOSOLIDS PRODUCTS

Biosolids are produced at the District's Stickney, Calumet, Egan, and Hanover Park WRPs. All biosolids are produced through anaerobic digestion and meet the Exceptional Quality metal concentration limits of the 40 Code of Federal Regulations (CFR) Part 503 rule (Table 3 of Section 503.13). The District's biosolids can be classified into two groups. The standard group of biosolids products is produced through standard operation of the solids processing trains. The non-standard group of biosolids products is produced only occasionally due to temporary planned or unplanned modifications to the standard operation of solids processing trains.

Site-specific designations and adjusted standards that dictate biosolids quality and utilization

- **IPCB Adjusted Standards (AS 95-4 and 02-03)** – This adjusted standard, originally granted to the District in 1995 by the Illinois Pollution Control Board allows the use of lagoon-aged (at least 1.5 years) air-dried (at least 65 percent solids content) biosolids for establishing the final vegetative layer on landfills as a landfill final cover. Class A status is not a requirement for this standard.
- **USEPA Site-Specific Process to Further Reduce Pathogens (PFRP) Certification** – This certification of the Calumet and Stickney WRP solids processing trains was granted in 2002. The certification specifies that biosolids produced by these processing trains in accordance with all parameters specified in the certification are designated Class A. Any biosolids that do not comply with any of the codified parameters for the solids processing trains are to be isolated from PFRP-compliant biosolids and must be tested to meet the Part 503 pathogen (virus and helminth) requirements to be designated Class A. Currently, this certification must be renewed every two years.

Standard biosolids products

This group includes four biosolids products resulting from normal operation of the District's biosolids processing trains.

- **Centrifuge Wet (CW):** Stickney, Calumet, Egan WRPs – These biosolids are produced by centrifugation to approximately 25 percent solids content and meet the 40 CFR Part 503 Class B pathogen requirements. This product is most commonly used as a fertilizer for application to farmland.
- **Aged Cake Dry (ACD):** Stickney and Calumet WRPs – These biosolids are produced by centrifugation to approximately 25 percent solids, followed by aging in lagoons for at least 1.5 years, then air-dried to at least 65 percent solids content, and meet the 40 CFR Part 503 Class A pathogen requirements and the IPCB adjusted standards. This product is most commonly used as landfill final cover or under the Controlled Solids Distribution program as a fertilizer or soil amendment on areas such as recreational fields and golf courses, and for reclamation of urban soils.
- **Aged Low Solids Dry (ALD):** Stickney and Calumet WRPs – These biosolids are produced by aging of low solids biosolids in lagoons for at least 1.5 years followed by air-drying to at least 65 percent solids content, and meet the 40 CFR Part 503 Class A pathogen requirements and the IPCB (AS 02-03). This product is most commonly used as landfill final cover or under the Controlled Solids Distribution program as a fertilizer or soil amendment on areas such as recreational fields and golf courses and for reclamation of urban soils.
- **Liquid Biosolids (LB):** Hanover Park WRP – This product consists of liquid biosolids of approximately 5 percent solids content and meets the 40 CFR Part 503 Class B pathogen requirements. The liquid biosolids are stored and thickened in lagoons and are utilized as a fertilizer for application to farmland by subsurface injection at the Fischer Farm located at the Hanover Park WRP.

Non-standard biosolids products

This group consists of three biosolids products that are produced through planned or unplanned temporary modifications to the normal operation of the District's biosolids processing trains. Their production and subsequent utilization are not always anticipated far in advance.

- **Un-aged Cake Dry (UCD):** Stickney and Calumet WRPs – These biosolids are produced by air-drying CW biosolids to approximately 65 percent solids content, and meet the 40 CFR Part 503 Class B pathogen requirements. These biosolids also are produced by storage of CW biosolids in lagoons for less than 1.5 years, followed by air-drying to approximately 65 percent solids content. This product can be used as landfill daily cover (most common) or as a fertilizer for application to farmland.
- **Un-aged Low Solids Dry (ULD):** Stickney and Calumet WRPs – These biosolids are produced by storage of low solids biosolids in lagoons for less than 1.5 years, followed by air-drying to approximately 65 percent solids content, and meet the 40 CFR Part 503 Class B pathogen requirements. This product can be used as landfill daily cover (most common) or as a fertilizer for application to farmland. This product can also be tested to demonstrate compliance with Part 503 Class A requirements and can then be used in Controlled Solids Distribution projects.

- **Unsuitables (U):** Occasionally, small amounts of biosolids are produced that are unsuitable for beneficial reuse because of irregularities such as the presence of debris or rocks. These biosolids are usually managed through disposal in municipal solid waste landfills.

DESCRIPTION OF CURRENT MARKETS

Current biosolids outlets utilized by the District include farmland application, landfills (daily and final cover), and Controlled Solids Distribution. All land applications of the District's biosolids are conducted in compliance with the 40 CFR Part 503 regulations, the Illinois Environmental Protection Agency (IEPA) Part 391 Standards for Utilization of Biosolids, and all site-specific permits.

Farmland application

The farmland application program consists of various components such as, CW biosolids, ALD biosolids and LB land application. In the Class B centrifuge cake program, CW biosolids is the most common biosolids product utilized. The biosolids are used under this program as a nutrient source for crops in Cook and other nearby counties in Illinois. In this outlet, the District pays a contractor to truck the biosolids either directly from the centrifuge hopper or from holding areas and lagoons at LASMA or from the Calumet WRP solids drying areas to farmland application sites. Multi-year contracts are awarded through competitive bidding on a cost per wet ton basis. The contractor is responsible for procuring the application sites, and the terms of biosolids use are between the contractor and the farmer. The District provides oversight of the program to ensure that the land application of biosolids is conducted in accordance with regulations and permits, and that the contractor's activities help in improving the public's perception of the farmland application program. The land application program is conducted under separate IEPA permits issued to the District and the contractor.

In the Fischer Farm land application program, all biosolids produced at the Hanover Park WRP are utilized on the District's Fischer Farm, which is a 130-acre site located on the grounds of the WRP. The LB are held in storage lagoons and a contractor applies the material by subsurface injection approximately twice a year; in the spring and fall. Corn is grown on the farm annually and the harvested crop is used for either animal feed or ethanol production. This land application program is conducted under a permit issued by the IEPA.

Landfill daily and final cover

Biosolids can be utilized in non-hazardous waste landfills as a daily cover and as a final cover. Biosolids utilization under this program is conducted in accordance with 40 CFR Parts 258 and 261. Biosolids utilization in these outlets is usually conducted through contracts with the landfill owners or operators in which the District pays tipping fees and the cost of hauling. The biosolids products most commonly utilized as landfill daily cover are UCD and ULD biosolids. Biosolids used as landfill final cover must meet the specifications of IPCB AS 03-02 are permitted by IEPA. This includes the ACD and ALD biosolids. Class A pathogen criteria are not required to be met for landfill final cover.

Controlled solids distribution

In the Controlled Solids Distribution (CSD) program, Class A biosolids are utilized as a nutrient-rich soil amendment for construction or renovation of recreational areas (such as golf courses, sports fields, and parks) and as a fertilizer topdressing on those areas. This program allows the use of biosolids under the CSD permit issued by the IEPA, and removes the permitting burden from the individual biosolids users. The District has committed to use only Class A ACD and ALD biosolids under this program. Currently, the biosolids are delivered free of charge to biosolids users. Technical guidance for proper use of biosolids is also provided by the District.

CENTRIFUGE WET BIOSOLIDS TO BIOSOLIDS PELLETIZING FACILITY

This outlet will consist of the conveyance of CW biosolids from the Stickney WRP to a pelletizing facility located on the plant grounds, which will be owned and operated by a private contractor, Metropolitan Biosolids Management, LLC (MBM). This facility is contracted to utilize approximately 150 dry tons/day (54,600 dry tons/year) of Stickney centrifuge cake for a 20-year contract period. MBM is responsible for managing the utilization of the pelletized biosolids.

BIOSOLIDS PRODUCTION AND UTILIZATION PROJECTION

District total

Table 1 details the entire District's projected production and amount to each utilization outlet. The production amount represents the biosolids that are generated from the digester. Since operations are not in steady state, the quantity of biosolids produced in any given year does not necessarily equal the quantity of biosolids utilized.

Table 1. Total district's biosolids production and utilization in dry tons[a]

Year	Plant Production[b]	Land Application	Landfill Daily Cover	Landfill Final Cover or CSD	Centrifuge Cake to Pelletization
2006	177,535	78,569	14,211	42,389	0
2007	177,535	78,569	18,000	37,839	40,950
2008	177,535	78,569	0	51,600	54,600
2009	177,535	78,569	0	56,600	54,600
2010	177,535	78,569	0	56,600	54,600

[a]*Estimate as of April 2006*
[b]*Plant production does not equal utilization because of non-steady state conditions*

Stickney water reclamation plant

It is estimated that approximately 140,000 dry tons of biosolids will be generated annually at the Stickney WRP for the next five years. In 2006, the estimated quantity of biosolids utilized from the Stickney WRP was 100,600 dry tons; 59,000 dry tons for farmland application and 41,600 dry tons utilization as daily/final cover or controlled solids distribution. The remaining 39,400 dry tons produced was estimated to be further processed and utilized in the subsequent years.

The pelletizing facility was scheduled to commence operations in 2007. If this operation is successful, the plan for 2007 through 2010, assuming steady-state conditions exist, is to produce and utilize a total of 140,000 dry tons per year. However, it is difficult to determine when or if steady state conditions could exist in the next five years due to the uncertainty of operations at the pelletizing facility and the outlet availability for controlled solids distribution. Table 2 details Stickney WRP's biosolids and utilization for 2006 through 2010, shown in non-steady state conditions. When Stickney WRP's operations reach steady state conditions, 59,000 dry tons will be allocated for farmland application, 54,600 dry tons will be utilized from the pelletizing facility, and the remaining 26,400 dry tons will be available for landfill daily/final cover or controlled solids distribution.

Table 2 – Stickney WRP's biosolids production and utilization in dry tons[a]

Year	Plant Production[b]	Land Application	Landfill Daily Cover	Landfill Final Cover or CSD	Centrifuge Cake to Pelletization
2006	140,000	59,000	14,211	27,389	0
2007	140,000	59,000	18,000	21,839	40,950
2008	140,000	59,000	0	41,600	54,600
2009	140,000	59,000	0	41,600	54,600
2010	140,000	59,000	0	41,600	54,600

[a]*Estimate as of April 2006*
[b]*Plant production does not equal utilization because of non-steady state conditions*

Calumet water reclamation plant

The estimated quantity of biosolids produced for the next five years at the Calumet WRP is approximately 30,000 dry tons per year. The estimated quantity of biosolids for utilization is also approximately 30,000 dry tons per year. Fifteen thousand dry tons per year will be allocated for land application and 15,000 dry tons per year will be allocated for landfill daily/final cover or controlled solids distribution. Table 3 details Calumet WRP's biosolids utilization for 2006 through 2010. Calumet WRP manages their biosolids operations at near steady state conditions.

Table 3. Calumet WRP's biosolids production and utilization in dry tons[a]

Year	Plant Production[b]	Land Application	Landfill Final Cover or CSD
2006	30,000	15,000	15,000
2007	30,000	15,000	16,000
2008	30,000	15,000	10,000
2009	30,000	15,000	15,000
2010	30,000	15,000	15,000

[a] *Estimate as of April 2006*
[b] *Plant production does not equal utilization because of non-steady state conditions*

Egan water reclamation plant

The estimated quantity of biosolids generated annually at the Egan WRP is approximately 6,700 dry tons. However, starting in the summer of 2006, an approximate 25% increase in biosolids production was expected for the duration of 12 months due to the addition of ferric chloride for chemical phosphorus removal. Typically, Egan utilizes approximately 5,400 dry tons through farmland application, either directly to the farms from the centrifuges or after hauling to LASMA or Calumet during the off-season. The remaining 1,300 dry tons (includes a combination of centrifuge centrate and digester draw) are pumped to the North Side WRP. Table 4 details Egan WRP's biosolids utilization for 2006 through 2010.

Table 4. Egan WRP's biosolids production and utilization in dry tons

Year	Plant Production	Land Application	Trucked to LASMA, Calumet	Biosolids to NSWRP[b]
2006	6,685[a]	3,719	1,670	1,296
2007	6,685[a]	3,719	1,670	1,296
2008	6,685	3,719	1,670	1,296
2009	6,685	3,719	1,670	1,296
2010	6,685	3,719	1,670	1,296

[a] *Does not include projected increase in solids due to chemical phosphorus removal*
[b] *Includes centrifuge centrate and digester draw*

Hanover park water reclamation plant

The Hanover Park WRP generates and utilizes approximately 850 dry tons per year of biosolids out of the digesters, which are injected into the farm fields at Fischer Farm. Hanover Park WRP's biosolids utilization for 2006 through 2010 is expected to be constant.

BIOSOLIDS MARKETING PLAN

Background

The District's Biosolids Management Plan provides descriptions of the biosolids products and the current market in which these products are utilized. The products that are generated from standard operation of the solids processing trains are Class B CW biosolids, Class A ACD and ALD biosolids, and Class B LB. The Class B LB are managed through application on a dedicated land application site (Fischer Farm), which has the capacity for long-term continuous use under its current operating permit. Therefore, no marketing effort is required to ensure utilization of this product in the long term. The other products are currently utilized through farmland application, landfill daily and final cover, controlled solids distribution, and utilization at the pelletizing facility. Except for the utilization at the pelletizing facility, which is under a long-term contract, biosolids utilization through these outlets compete to some extent with other options available in the market, and would require some planning to address the overall goals of the District's biosolids management program. Therefore, the Biosolids Marketing Plan is designed to address the overall goals of the biosolids management program outlined in the Biosolids Management Plan. The Marketing Plan covers the following:

- Evaluation of the biosolids utilization outlets.
- Identification of activities that should be conducted to attain the goals of the biosolids management program.
- Establishment of targets for quantities of biosolids to be utilized under each of the outlets.
- An approach for continuous assessment and modification of the Marketing Plan.

EVALUATION OF THE BIOSOLIDS UTILIZATION OUTLETS

Recent history of utilization of districts biosolids

The quantities of biosolids utilized in the various outlets during 1998 to 2005 are presented in Table 5. The data show most of the District's biosolids are beneficially used, primarily through land application. The quantity of unsuitable biosolids generated from cleaning of old residual material from the bottom of holding lagoons declined sharply with time and is currently minimal. Except for the utilization of ACD and ALD biosolids at the Fulton County site, which was terminated in 2004, the quantities of biosolids utilized in the various outlets fluctuated widely during this period. These fluctuations are due to several factors, such as one-time utilization on large projects and delays in issuing utilization contracts. Most of the District's biosolids have been utilized as Class B CW biosolids through the Farmland Application Program.

Since the inception of the Controlled Solids Distribution program, the amount of biosolids utilized through repeated customers represent only a small fraction of the ACD and ALD biosolids production. Most of the biosolids utilized in the program are through large single-use projects, resulting in large fluctuations in the quantities of biosolids utilized under the program annually. For example, almost 50,000 dry tons in 1998 (Table 5) were used for construction of Water's Edge golf course. Due to the termination of biosolids application at the Fulton County site, which utilized ACD and ALD biosolids during 1998 to 2004, about 20,000 dry tons of this material are available for utilization annually through the Controlled Solids Distribution program or landfill final cover.

Comparison of the biosolids outlets

A comparison of the most feasible biosolids utilization options is important for setting targets on the amount of biosolids to be utilized through each outlet. In addition, this comparison helps in prioritizing the allocation of resources for improving the overall cost effectiveness of the biosolids management program.

- **Farmland Application:** The farmland application program has been the largest continuous biosolids outlet since its inception in the late 1990s. The success of the program is due primarily to the cost effectiveness of production and utilization of Class B CW biosolids compared to Class A biosolids, the large land base in the nearby counties, and the ability of the District to run the program through contracts. The utilization on farmland is seasonal, but the times at which biosolids can be applied to farmland (spring and fall on corn and soybean fields, and summer for wheat fields) provide operational flexibility. The long-term sustainability of the program is uncertain, due to potential for public oppositions to the farmland application practices as experienced by many municipalities throughout the U.S., and the potential impact of future regulations on biosolids phosphorus, which might severely decrease the feasibility of the practice. A few occurrences of public opposition, which typically occurs at the rural-urban interface, could be detrimental in the entire program. However, compared to experiences elsewhere, the District's program has received little public opposition.

  Since the demand and availability of land for utilization of District biosolids under the farmland application program vastly exceed the amount of Class B biosolids available annually, it is unnecessary to allocate significant resources directly to increase the demand in this market. Instead, more indirect efforts to decrease potential for public opposition and the impact of future regulations will help to increase the long-term sustainability of the program. Some of the current activities that are serving this purpose include the farmland research and demonstration plots located in Will and Kankakee Counties, the vigilant oversight of farmland application contracts provided by the Maintenance and Operations (M&O) and the Research and Development (R&D) Departments, and the biosolids phosphorus studies that are conducted in collaboration with the Illinois Environmental Protection Agency. Therefore, in this Biosolids Marketing Plan, no direct marketing activities are prescribed for the farmland application program.

- **Landfill:** Due to the relatively high cost of managing the biosolids through utilization at landfills (final or daily cover), this outlet serves primarily as a backup to other primary markets that are more cost effective and to maintain diversity in the biosolids management program. Similar to the farmland application program, it is unnecessary to implement direct marketing activities to increase the quantity of biosolids that are managed through this outlet. However, the District will continue to keep up-to-date with the availability of opportunities to utilize biosolids through these outlets and assess their cost-effectiveness with respect to the overall goal of the Biosolids Management Plan.

Table 5. Recent history (1998 through 2005) of utilization of district biosolids

Utilization	1998	1999	2000	2001	2002	2003	2004	2005
	Beneficial Reuse[1]							
Farmland	15,634 (9)[2]	39,853 (21)	84,848 (42)	126,569 (67)	31,700 (21)	84,320 (40)	84,997 (46)	65,854 (39)
Fulton County	17,951 (11)	18,008 (9)	17,804 (9)	22,000 (12)	20,495 (14)	20,276 (10)	22,037 (12)	0
Controlled Solids	50,984 (30)	11,316 (6)	7,720 (4)	3,095 (2)	4,810 (3)	23,922 (11)	680 (0.4)	33,923 (20)
Landfill Final Cover	48,192 (28)	85,501 (44)	47,687 (24)	1,490 (1)	31,499 (21)	30,919 (15)	18,408 (10)	42,680 (25)
Landfill Daily Cover	36,704 (22)	37,675 (20)	43,846 (22)	35,733 (19)	59,507 (40)	49,987 (24)	59,447 (32)	27,577 (16)
Total Beneficial	169,465	192,353	201,905	188,887	148,011	209,424	185,569	170,034
	Non-beneficial							
Landfill Co-Disp.	59,885 (26)	66,434 (26)	31,497 (13)	12,698 (6)	12,381 (8)	3,925 (2)	2,293 (1)	2,759 (2)
Grand Total	**229,350**	**258,787**	**233,402**	**201,585**	**160,392**	**213,349**	**187,862**	**172,793**

[1]*Does not include dedicated land application of Hanover Park WRP liquid biosolids at the Fischer Farm.*
[2]*Values in parentheses represent percentage of total (Grand Total) utilization.*

- **Controlled Solids Distribution:** The utilization of biosolids in the Chicago area under the Controlled Solids Distribution program provides one of the best opportunities to utilize the inherent benefits of biosolids, as a soil conditioner to enhance the physical characteristics and nutrient content of poor quality soils, and as a topdressing for their fertilizer value. In addition, utilization in this market includes a wide diversity of customers (educational institutions, park districts, golf courses, and topsoil vendors) and uses (e.g. soil conditioner, fertilizer topdressing, reclamation of contaminated soils). Therefore, if the District can implement an effective plan to attract these customers, the use of biosolids in the Chicago area through the Controlled Solids Distribution program can provide a long-term sustainable market. This program has the potential for significant public education benefits. Another significant advantage of the Controlled Solids Distribution program is the proximity to utilization sites, which typically results in lower hauling cost compared to the other outlets. The hauling cost can decrease further if more biosolids are utilized in the city. Emphasis should be placed on developing projects with sustainable customers who will be reliable repeat users.

The factors limiting the growth of the Controlled Solids distribution program are interrelated. The large fluctuations in the quantities of biosolids utilized in the program annually are due primarily to periodic large projects. These large projects are not always beneficial to the long-term sustainability of the program for two reasons. Firstly, the large projects tend to utilize most of the ACD and ALD biosolids available for distribution under the program, and therefore the availability to repeat customers for smaller projects cannot be guaranteed. Secondly, the request and project commitment for these large quantities are usually not planned well in advance to allow the District to route biosolids through the process trains to meet the demands. Therefore, the biosolids marketing strategy will be tailored to give priority to long-term sustained outlets. For the large projects, the District staff will work more closely with project managers and other decision-makers to get more details on advance planning to increase the amount of biosolids that are routed to air-dried Class A production for these projects. Another factor that has limited the growth of this market is the fact that projects are not guaranteed by contractual obligation. Tailoring the marketing to long-term sustainable outlets should also minimize the negative impact of this factor.

BIOSOLIDS UTILIZATION TARGETS

The forecasted production and utilization of District biosolids from 2006 through 2010 is presented in Table 1. Steady state quantities of centrifuge cake for the period are allocated to the farmland application program (multi-year contracts) and the pelletization plant (contract with Metropolitan Biosolids Management, LLC). Based on the demand of other biosolids outlets, targeted quantities for the farmland application program could be adjusted at the beginning of contract cycles.

The quantities targeted to Controlled Solids Distribution were determined based on the amount of Class A ACD and ALD biosolids typically available from the Calumet WRP, current demand, and expected response to biosolids marketing activities. The Calumet and Stickney WRPs currently have PFRP-certified solids processing trains for production of Class A ACD and ALD biosolids. However, due to maintenance activities in the operation of the Stickney WRP processing trains (taking digesters out of service for cleaning and rehabilitation), the Stickney WRP will not produce Class A biosolids through PFRP-compliance before 2009, but the ACD and ALD biosolids produced can be tested to demonstrate Class A status. Because of the difficulties involved in using the Class A testing requirement to produce Class A biosolids for projects in a timely manner, during 2006 through 2010, the Calumet WRP is designated as the only source of Class A biosolids for marketing.

Historically, the schedules of Controlled Solids Distribution projects have been uncertain. However, the biosolids marketing activities are designed to promote the use of biosolids and to increase the rate at which potential projects materialize. For 2007, advance requests are available for about 6,500 dry tons. Because we expect additional requests in response to the marketing activities, the 2007 target is set at about 25 percent above the advance request. Any portion of this quantity (8,000 dry tons) that is not utilized will have to be carried into 2008, or utilized through alternative outlets. A similar approach will be used in subsequent years. The steady increases in the target during the five-year period up to 15,000 dry tons is based on the expectation that the biosolids marketing activities (including the topsoil manufacture) will result in a steady increase in demand. We believe that 15,000 dry tons annually is sufficient for maintaining diversity of the biosolids utilization program. If the demand for biosolids through the Controlled Solids Distribution program increases significantly, the targets will be reassessed with respect to impacts on the cost effectiveness of the biosolids management program.

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Kansas – Lawrence Utilities Management System: For a better environment and safer work place

BACKGROUND

Lawrence is located in northeast Kansas, approximately 30 miles west of Kansas City and 20 miles east of Topeka, the state's capital. The University of Kansas and Haskell Indian Nations University both make Lawrence their home. These, as well as a good quality of life and safe small town feel, all contribute to relatively steady growth over the past several years. Lawrence had a population of approximately 90,000 people in 2007.

The City's Department of Utilities manages and maintains one wastewater treatment plant and two water treatment plants, as well as the associated distribution and collections systems, laboratories, and engineering services. The activated sludge wastewater plant treats 12 MGD under normal treatment conditions and 25 MGD during wet weather. Excess flow is treated through a ballasted flocculation or Actiflo® system, which was the first application of this technology in wastewater treatment in the United States. Anaerobic digesters stabilize the solids to meet Class B biosolids regulations. Belt presses thicken the biosolids to approximately 22% solids. Conveyors move the biosolids to covered storage, where they are stored for 4-6 months. Typically during the fall following harvest and spring prior to planting, the biosolids are applied as a fertilizer and soil conditioner to privately owned agricultural fields within approximately 15 miles of the city. A small portion of the biosolids are set aside, air-dried, tested to assure that they meet EPA EQ requirements, and distributed for residential uses. Biosolids have been re-used in some fashion since 1956.

The City's water treatment plants provide drinking water from two sources to the City and several wholesale customers. The Clinton Water Treatment Plant draws water from the Clinton Reservoir and treats 30 MGD. The Kaw River Treatment Plant draws water from the Kansas River and alluvial wells and treats 16.5 MGD. Treatment processes at both plants include pre-sedimentation, primary settling, secondary settling, and filtration.

NATIONAL BIOSOLIDS PARTNERSHIP EMS FOR BIOSOLIDS

The City of Lawrence has a very active biosolids reuse program. In the mid-1990's the Water Environment Federation, the National Association of Clean Water Agencies, and the US Environmental Protection Agency formed a partnership called the National Biosolids Partnership. The NBP's focus was to increase the public's understanding and acceptance of biosolids reuse activities across the nation. One of the methods proposed was to develop an Environmental Management System for biosolids generators to implement into their programs. One of the outcomes anticipated from this venture was to increase the generator's credibility and the public's confidence.

In 1999, the City of Lawrence agreed to undergo a gap analysis with NBP consultants, who were in the beginning stages of planning the environmental management system. In May of 2000, the City of Lawrence was asked to participate as a demonstration project. This required commitment to developing and implementing an EMS for Biosolids. The Lawrence Wastewater Utility became one of 27 charter demonstration agencies to participate in this program. Lawrence had several reasons for joining this group of 27 agencies including:

- An opportunity to help set the standard
- At the time, most of the participants were very large generators. We saw the need for small/medium sized agency representation and contribution.
- Department management had heard about EMS's through EPA presentations and other venues. Lawrence has historically been very progressive.
- The potential increase in credibility and integrity of Utilities Department programs was anticipated to provide insulation or protection against negative outside influences, possibly from other generators in the region or other parts of the country.
- NBP offered training and consultant assistance in the development of the EMS, which benefited the demonstration agencies.

Lawrence proceeded with developing the EMS for Biosolids, which included attending training sessions sponsored by the NBP, discussions and assistance from the NBP-provided consultant, and reviewing and providing input to the NBP on guidance and training documents. This became a prolonged implementation process from 2000 to 2005 due to several contributing factors including:

- Significant trial and error experienced during the development of the individual programs, due to the development of the guidance and training by NBP and the input that the charter agencies were providing.
- During that time frame, the Lawrence Wastewater Treatment Plant was undergoing extensive construction to expand capacity, achieve compliance with anticipated regulatory changes, and renovate the facility. The construction project required a significant amount of employee time, which took time away from implementing the EMS for Biosolids.
- The required third party audit was somewhat daunting and intimidating especially for the first agencies to undergo audit and subsequent certification.

Agencies that commit to implementing an EMS for Biosolids now would expect to spend about 1 year doing so. The NBP has developed guidance and templates with the input of the charter agencies that provides new agencies with a lot of the information that was missing or that we helped develop in the beginning.

Upon completion of the third party audit, which is required by the NBP, the City of Lawrence became certified in late 2005. The Utilities Department management realized the potential benefits associated with implementing the NBP EMS for Biosolids. However it only applied to about 90% of the wastewater utility activities and processes at that time. Additionally the EMS for Biosolids applies to the entire biosolids value chain, including pretreatment, collections, primary and secondary treatment, solids stabilization, solids handling and storage, and reuse. The disinfection and effluent processes of the Wastewater Utility are the only areas not included in the EMS for Biosolids. Managing the Wastewater Utility differently based on the requirements of the EMS for Biosolids was not consistent with the management goals or methods of the Utility.

IMPLEMENTATION OF ISO 14001 AND OHSAS 18001

With the need to maintain consistent management methods throughout all Wastewater Utility processes, the Utility's Management directed staff to expand the EMS to the entire Wastewater Utility. Since the NBP developed the EMS for Biosolids with ISO 14001 as a model, Lawrence expanded and adapted the EMS for Biosolids to also be consistent with the ISO 14001 standard.

The ISO 14000/14001 environmental management standards help organizations minimize how their operations harm the environment, which means their adverse changes to air, water, or land, and to comply with applicable laws and regulations. ISO 14001 is the international specification for an environmental management system (EMS) against which organizations are assessed. It outlines requirements for:

- establishing an environmental policy
- determining environmental aspects and impacts of their products, activities, and services
- planning environmental objectives and measurable targets
- implementation and operation of programs to meet objectives and targets
- checking and corrective action
- management review.

The overall idea is to establish an organized approach to systematically reduce the impact of the environmental aspects, which an organization can control, like the NBP EMS for Biosolids. As with other ISO standards and the EMS for Biosolids, certification is performed by third-party auditors.

The Lawrence Wastewater Utility's management has also made a serious commitment to the health and safety of its employees and the community surrounding its facilities. The significance of safety in the workplace and the risks involved with wastewater and water treatment prompted the Utility's management to direct the implementation of an additional specification for occupational health and safety, OHSAS 18001.

OHSAS 18001 is the assessment specification for Occupational Health & Safety Management Systems and is the framework that allows an organization to consistently identify and control its health and safety risks, reduce the potential for accidents, assist in regulatory compliance, and improve overall performance. It was developed in response to the need for companies to meet their health and safety obligations in an efficient manner. The following key areas are addressed by OHSAS 18001:

- Planning for hazard identification, risk assessment and risk control
- OHSAS management program
- Structure and responsibility
- Training, awareness and competence
- Consultation and communication
- Operational control
- Emergency preparedness and response
- Performance measuring, monitoring and improvement

The NBP EMS for Biosolids standard, ISO 14001 standard, and OHSAS 18001 specification are similar in requirements and basic elements, which promoted the integration of the three into one system, using the most rigorous of requirements consistently throughout the Wastewater Utility. This method was developed over the alternative of developing three separate management systems, which would duplicate efforts in many of the requirements.

Integration held some challenges, including the combining of an environmental impact and occupational health and safety risk analysis with the method prescribed by the EMS for Biosolids. Lawrence hired a consultant to assist with this combined exercise. Although working through this process was educational and worthwhile, the process chosen by this consultant proved to be considerably difficult and detailed. This level of complexity proved to be hard to duplicate for future reviews and completely unnecessary, where easier and simpler methods were equally effective.

Other differences included the requirement by the EMS for Biosolids of an annual performance report, which is not required by either ISO 14001 or OHSAS 18001. The integrated system includes performance reporting on ALL activities including wastewater activities, biosolids, and occupational health and safety. The overall implementation of the EMS included several key milestones, which are as follows:

- Development of a manual to describe the management system
- Awareness training for staff
- Conducting an environmental impact and safety risk assessment of activities, which included a review of where these impacts and risks occurred (critical control points) and what was done to minimize them (operational controls).
- Defining legal and other requirements as a baseline

- Redefining our documentation, recordkeeping, and monitoring
- Determination and clarification of roles and responsibilities
- Conducting an internal audit as well as undergoing a third party independent audit

Overall, this was not a complete change of the way things were being done. It primarily included a refining of current practices to make the process more efficient in time and resources as well as functional and purposeful. Due to the continual improvement element of the management system, there is an on-going cycle of setting, reviewing, and completing goals based on legal requirements, significant environmental impacts and health and safety risks, and other contributing factors. It also puts into place a corrective and preventive action process that is designed to evaluate the root cause and develop a plan to correct the problem and prevent it from happening in the future.

Third party audit of this integrated management system occurred in October 2006. Through the third party audit process, findings may include major nonconformances, minor nonconformances, and opportunities for improvement. Major nonconformances must be corrected within a shorter period of time and indicated possible system problems. Minor nonconformances have a longer period of time for correction and are minor inconsistencies with the standard. Opportunities for improvement are optional for correction and offer areas where the agency can make an improvement, but is not a nonconformance with the standard or specification.

During the audit of this integrated system, a major nonconformance was identified and required correction within 3 months. This correction was completed and accepted by the auditor and the certification achieved in December 2006.

EXPANSION TO WATER UTILITY

Recent organizational changes have included the reorganization of the Department of Utilities, which consists of Water and Wastewater Utilities and associated other support divisions, to break down many of the "silos" that existed between divisions and work groups. This initiative included consistency throughout the Department work groups, and thus the expansion of the management system to include drinking water treatment and distribution systems. The Lawrence Utilities Management System or LUMS, as it is referred to, underwent third party audit in October 2007 and received the expanded certification in February 2008. This was following a major nonconformance corrected in January 2008.

Each of the standards and specification require a commitment to continual improvement. After receiving two different major nonconformances and an array of minor nonconformances and opportunities for improvement, the understanding that this is an important part of the process is paramount. Although it may be difficult for organizations to accept audit results that are less than perfect, a perfect audit report is likely an indication that the auditor may not be doing a thorough review of the system. Due to the overriding effort to "continually improve" the system, an audit report that does not challenge an agency to do better and make improvements at each audit is a disservice to that agency and ultimately a waste of agency funds.

BENEFITS OF THE LUMS

The features of the LUMS are successfully being used for all general management activities, not primarily environmental and occupational health and safety. They have been incorporated fully into the day-to-day methods of doing business. This management system could easily be incorporated by other municipalities and government agencies with success.

The Lawrence Utilities Management System has been directly or indirectly responsible for the following outcomes:

- A second wastewater treatment plant was sited with minimal public concern or public relations issues. This saved the City approximately $100,000 that had been anticipated for public relations activities.
- Overall citizen knowledge and awareness is very high, which has helped us get projects completed with a minimal amount of delays.
- Overall staff feeling is that teamwork between the various work groups has improved.
- It has led to a reorganization of the safety committee to include responsibilities that are more substantial and valuable to the department.
- The EPA recognized Lawrence for Exemplary Biosolids Management and Operations and Maintenance Excellence in 2005 through their National Clean Water Act Recognition Awards.
- SCADA (automation) controls have been expanded to lift stations to increase mechanical reliability and decrease sewage backups.
- Additional mixing capacity in sludge holding tanks has increased the quality of sludge digestion which has decreased odor and increased the percent solids attainable from the belt presses. Ultimately this has decreased fuel usage in land application by 13.5%.
- Lift station #48 was sited and line placement went through numerous properties. Due to the public participation element of the management system, the public was able to voice their concerns and interests, which led to relative ease in completing this project on time and under budget.
- Overall training, competency, and communications of staff have improved greatly.
- EPA accepted the Lawrence Wastewater Utility as a member of the EPA Performance Tracks Program.
- The electricity consumption has remained relatively constant, despite a plant expansion that took the plant from a 9 MGD plant without nitrification to a 12.5 MGD plant with nitrification. (Approximately a 200% increase in treatment capability).

CONCLUSION

Implementation of the integrated management system was challenging at times. However, the results that we have experienced directly and indirectly from it have been very impressive. Time formerly spent in unproductive meetings is now used efficiently to discuss the most pertinent topics for review by management. The corrective action method has not only increased the public's trust by demonstrating improvement, but also increased confidence from the City's management and elected officials in the operation, maintenance, and general activities of the Department of Utilities. In addition to the continued improvement that the Department anticipates with the management system as it currently exists, management is assessing the potential benefits from incorporating ISO 9001 standards. ISO 9001 follows similar methodology as the other standards, but is directed toward customer service and consistency in the product and service provided to the public. Although a decision has not been made regarding the expansion of the management system to include ISO 9001, the Department's service (wastewater treatment) and product (drinking water) would make a logical and potentially beneficial step to take.

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Michigan – City of Grand Rapids Wastewater Treatment Plant

BACKGROUND

The Grand Rapids Wastewater Treatment Plant (GRWWTP), located in Grand Rapids, MI, provides wastewater collection and treatment for the City of Grand Rapids and 14 surrounding communities, totaling approximately 360,000 customers within a 200-square mile geographical area. The wastewater plant has a design capacity of 61 MGD and currently has an average daily flow of 51 MGD. In 1998 the existing stabilization system failed, a low pressure oxidation unit manufactured by Zimpro, and the City began contracting with Synagro Midwest for Biosolids Processing.

The GRWWTP was part of a third round of agencies participating in the National Biosolids Partnership (NBP) Environmental Management System (EMS) for Biosolids. Development of our EMS program started in early 2005 with the creation of an internal EMS team. The GRWWTP Biosolids EMS was formally certified by the NBP in December 2006 and successfully completed the first annual interim audit in November 2007.

In recent years, the staff of the GRWWTP and the City of Wyoming Clean Water Plant (CWP) has each explored alternatives for the future of their respective biosolids programs. Both CWP and GRWWTP staff anticipate that regulatory requirements in the future will cause changes as to how biosolids are processed and utilized, and that significant capital investments will be required not only to keep pace with regulatory changes, but also to replace aging facilities and equipment. In addition, the existing programs are at the mercy of economic factors beyond the control of each City, including fuel costs, landfill tipping fees, and the loss of biosolids application land due to ever-expanding urban development. On April 22, 2004 the Mayors of Grand Rapids and Wyoming celebrated Earth Day by signing the official Articles of Incorporation of the Grand Valley Regional Biosolids Authority (GVRBA).

SELECTION OF DISPOSAL PRACTICE

The City produced a total of approximately 15,000 dry tons of biosolids in 2007. All biosolids were placed in a landfill either producing methane and utilizing them as a renewable energy source or planning to.

ECONOMIC INFORMATION

The costs of operations based on 2006 budgets and costs are as follows:

- Past capital costs attributable to Biosolids handling were less than 0.1% of the capital budget in 2006, with a future capital costs at expected to be less than 10%.
- Biosolids account for 27 % of the Plants Operations & Maintenance (O&M) budget.
- User charge to customers for treatment of sewage per 1,000 gallons: $5.02
- One decatherm of natural gas: $9.10
- One kilowatt hour electricity: $0.0618
- Contractor processing cost is $199.85 per dry ton (does not include utilities)

AGRICULTURAL LAND APPLICATION

Land application is not currently utilized by the City. In long-term facilities planning there is consideration given to installation of digesters and/or a heat drying process as part of the GVRBA project.

LANDFILL

The biosolids are dewatered with centrifuges then utilized by three local landfills as a source of organics and organisms to enhance the landfill bioreactor technology, which they utilize to accelerate biological breakdown of the waste and increase "biogas" production. The dewatered biosolids with other organics are mixed at a ratio of four (4) parts municipal solid waste with one (1) part organics. Resulting in;

- Expedited startup (gas production) of the landfill when dewatered biosolids are used as a source of microorganisms and organics.
- Increased "biogas" production.
- "Biogas" offsets fossil fuel usage.
- Increase rate of decomposition of solid waste material in the landfill.
- The dewatered biosolids fill in the voids and require minimum landfill space.
- Shorter closure period after the landfill stops accepting waste.
- Biosolids help abatement of greenhouse gases because they help to stabilize "biogas" production for beneficial uses versus flaring or uncontrolled releases.

The "biogas" recovered from these landfills is beneficially utilized in several environmentally friendly ways. One of the landfills collects the "biogas" and then pressurizes and pumps it approximately three miles to a local soybean processing facility. There it is used to produce electricity, dry soybeans or in soy oil manufacturing processes. At another site the recovered "biogas" is used in generators to produce "green" electricity which helps offset the need for fossil fuels at generating plants. The third site plans to incorporate "biogas" recovery into its business plan in the future.

INCINERATION OPTION

Incineration is not a practice utilized by the City. In long-term facilities planning there is no consideration given to installation of incineration facilities per se.

FUTURE – GRAND VALLEY REGIONAL BIOSOLIDS AUTHORITY

Recently constructed pipelines will be used to transport solids approximately 3 miles between the CWP and the GRWWTP to maximize efficient use of solids processing equipment, future digestion and future production of heat-dried biosolids. A pumping station is under construction at the CWP to move the solids through the pipelines which consists of two (2) pipes at 8 inches inside diameter. New solids storage and dewatering are under construction at the GRWWTP with a spring 2009 startup planned.

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Ohio – Northeast Ohio Regional Sewer District

BACKGROUND

The Northeast Ohio Regional Sewer District (NEORSD) is an independent political subdivision of the State of Ohio that provides wastewater treatment and collection services for the City of Cleveland and 60 suburban communities. It has a service area that encompasses approximately 350 square miles and serves more than 1.1 million residents and businesses.

Since its inception in 1972, the NEORSD has invested $2.2 billion in projects that have substantially improved the quality of life in Northeast Ohio and have contributed to the rebirth of Lake Erie and the Cuyahoga River.

The NEORSD owns and operates three wastewater treatment facilities; known as the Easterly, Southerly and Westerly wastewater treatment plants. These facilities treat a combined average flow of approximately 230 million gallons of wastewater per day.

In 1938, the Easterly WWTP was placed into service. Given this plant's location, the residents insisted that sewage sludge (now known as biosolids) not be processed at the plant. As a result a 13-mile long force main was installed to pump the solids removed from the wastewater at Easterly to the Southerly WWTP for processing and disposal. Easterly's wastewater solids are still being pumped to Southerly and this process will continue for the foreseeable future.

BIOSOLIDS MANAGMENT

The NEORSD produces 90,000 – 100,000 wet tons of biosolids per year, of which 90% is incinerated in four multiple hearth incinerators located at the Southerly WWTP and two multiple hearth incinerators located at the Westerly WWTP. The balance is hauled to, and disposed of at, municipal solid waste landfills, which are located approximately 65 southeast of Southerly and 75 miles southeast of Westerly.

Southerly WWTP

Southerly's incinerators were originally placed into service in 1964 and upgraded in the late 1970s. These units have been properly maintained on a regular basis since the early 1980s.

Southerly's biosolids are unique, since they are thermally conditioned using the patented "Zimpro" process, which produces a Class A biosolids product. Prior to placing the Zimpro process into service, in 1981, the sewage sludge was chemically conditioned and dewatered with vacuum filters that produced a cake containing 18 – 22% solids. With the start-up of the Zimpro process, the solids content of the vacuum filter dewatered cake increased to 43%.

In 1997, the vacuum filters were replaced with new high solids centrifuges and the resulting cake currently contains 45 – 53% solids.

Southerly's four multiple hearth incinerators are equipped with waste heat boilers that produce steam for building comfort heat and various processes. Since this steam would have been produced by the plant's mid-sized package boilers, the waste heat boilers reduce natural gas consumption by approximately 120,000 million cubic feet (MCF)/year. This resulted in a cost savings to the NEORSD in 2004 of approximately $627,000, based on a natural gas rate of $5.20/MCF.

In 2000, the NEORSD received a beneficial reuse of biosolids award from the United States Environmental Protection Agency for the beneficial reuse of the heat contained within the incinerators' exhaust gases.

Southerly biosolids composition

The following are the average values for Southerly's biosolids during the 2007 calendar year:

Dry Solids	46%
Organic Matter (Volatile Solids)	58%
Zinc	953 mg/dry kg
Copper	404 mg/dry kg
Nickel	92 mg/dry kg
Mercury	1 mg/dry kg
Cadmium	14 mg/dry kg
Lead	99 mg/dry kg
Total Nitrogen (TKN)	22,450 mg/dry kg
P_20_5 (reported herein as P)	20,121 mg/dry kg
K_2O(reported herein as K)	1,576 mg/dry kg

Beneficial reuse of Southerly's biosolids incinerator ash

The incineration of biosolids results in the evaporation of water, the combustion of the organic matter (volatile solids), and an 85 – 95% reduction in volume. The final product is a non-toxic, non-hazardous, inert ash.

Southerly's four multiple hearth incinerators produce approximately 10,000 – 15,000 dry tons of ash per year or an average of 25,000 wet tons per year. The ash is mixed with water from the incinerators' exhaust gas scrubbers and transported to ash storage lagoons located to the south of the plant. From 1990 – 2007, the ash was removed from the lagoons approximately once every two to three years and used as clean fill material in Southerly's South Fill Area. The South Fill Area is an old sludge lagoon that was utilized by the City of Cleveland from the 1930s through the 1960s, and still contains a sizable quantity of sludge.

The transportation of ash from the lagoons to the South Fill Area has cost the NEORSD approximately $115,000 per year. The unit cost to haul ash to a landfill in 2004 was $50/ wet ton. As s result, it would have cost the NEORSD $1.2 million in 2004 to haul the ash to landfill for disposal. As a result, the beneficial reuse of Southerly's ash resulted in a $1.1 million cost savings to the NEORSD.

The South Fill Area reached its permitted capacity in 2007. As a result, starting in 2008, the ash will have to be hauled to landfill unless another beneficial use is found for it. Currently, NEORSD personnel are working with Entrepreneurs for Sustainability and other organizations in an attempt to find local beneficial reuse options for both Southerly and Westerly's ash.

Westerly WWTP

Westerly's two multiple hearth incinerators were constructed in the early 1970s, but not placed into service until 1983, due to problems associated with the construction of the Westerly WWTP. The units were shutdown in 1985 when the cost of landfilling biosolids dropped below Westerly's incineration costs. However, due to a spike in landfilling costs in 1988 and subsequent increases, the incinerators were returned to service in 1989. The units were renovated and upgraded in 1994 and 1995. At that point in time, heat exchangers were installed to transfer heat in the exhaust gases to the combustion air.

Westerly biosolids are chemically conditioned and dewatered using high solids centrifuges.

The following are the average values for Westerly's biosolids during the 2007 calendar year:

Dry Solids	34%
Organic Matter (Volatile Solids)	58%
Zinc	1,144 mg/dry kg
Copper	326 mg/dry kg
Nickel	54 mg/dry kg
Mercury	1 mg/dry kg
Cadmium	15 mg/dry kg
Lead	183 mg/dry kg
Total Nitrogen (TKN)	33,859 mg/dry kg
P205 (P)	15,114 mg/dry kg
K2O (K)	2,265 mg/dry kg

BIOSOLIDS MANAGEMENT COSTS

The following is a comparison of the biosolids management operational & maintenance costs to incinerate and landfill Southerly and Westerly's biosolids in the 2004 calendar year:

	Southerly WWTP	**Westerly WWTP**
Biosolids incinerated	75,503 wet tons	16,444 wet tons
Percent solids	47%	33%
Dewatering device	High Solids Centrifuges	High Solids Centrifuges
Biosolids conditioning	Thermal (Zimpro)	Chemical
Heat exchangers	No	Yes
Waste heat boilers	Yes	No
Natural Gas	$454,385	$400,415
Electricity	$279,661	$82,396
Labor (Operators)	$488,176	$281,845
Maintenance (plant personnel)	$262,525	$39,589
Ash Disposal	$115,000	$98,717
Totals Incineration O&M Costs	**$1,559,747**	**$902,962**
Total Incineration O&M Unit Cost	**$21.19/wet ton incinerated**	**$54.92/wet ton incinerated**
Steam production natural gas savings	120,702 MCF	-0-
Steam production natural gas savings	$627,110	-0-
Net Incineration O&M Costs*	**$972,637**	**N/A**
Net Incineration O&M Unit Cost*	**$12.88/wet ton incinerated**	**N/A**

** Net Incineration O&M Costs = Total incineration O&M costs – natural gas related cost savings attributable to the steam produced by the waste heat boilers.*

LONG-TERM RESIDUALS MANAGEMENT PLAN

Faced with potential regulatory changes that could have eliminated incineration as a viable biosolids management option and potential increases in its biosolids related management costs, the NEORSD decided to conduct a study to determine how it could most cost-effectively manage its biosolids over the next 25 years.

The study's Project Team thoroughly investigated the numerous biosolids management practices that are commonly used by similar municipal wastewater treatment agencies throughout the United States. These potential management options were compared against each other using standard economic and non-economic criteria. The highest ranked biosolids management alternatives were landfilling and incineration.

Based upon site-specific conditions at the NEORSD's three WWTPs, a detailed evaluation of the potential capital costs and annual O&M costs were developed for the various biosolids landfilling and incineration alternatives. Net Present Values (NPVs), based on the detailed up-front capital costs and ongoing O&M costs, were developed and used to compare the relative cost-effectiveness of the various alternatives. Site-specific issues (e.g., permitting requirements, sensitivity to increases in natural gas and transportation costs, staffing and maintenance requirements, biosolids storage requirements, number of trucks required to transport biosolids, etc.) were also analyzed.

The site-specific detailed analyses served as the basis for the NEORSD's long-term biosolids management plan, which was approved by its Board of Trustees in January 2005. The plan consists of the following:

- Continue incineration of biosolids at the NEORSD's Southerly and Westerly WWTPs, with landfilling as a backup;
- Replace Southerly's four existing multiple hearth incinerators (MHIs) with three new state-of-the-art fluidized bed incinerators (FBI);
- Continue pumping wastewater solids from the NEORSD's Easterly WWTP to the Southerly WWTP for processing and disposal;
- Continue to incinerate biosolids in the Westerly WWTP's two existing MHIs for at least the next 10 years. Re-investigate potential long-term management alternatives for Westerly's biosolids in 2012; and
- Continue to store ash in the Southerly WWTP's existing ash lagoons. Clean the lagoons once every two to three years and haul the material to landfill. Continue hauling Westerly's ash to a municipal solid waste landfill. Investigate potential ways to reduce the NEORSD's ash related landfilling costs, along with other potential beneficial uses for the ash.

Detailed information concerning the various management alternatives investigated; the results of the various economic, non-economic and detailed analyses; and the reasons behind the selection of incineration as the NEORSD's long-term biosolids management alternative are contained in NEORSD's Long-Term Residuals ManagementPlan[1].

REFERENCES

Robert P. Dominak, et. al., "Long-Term Residuals Management Plant for the Northeast Ohio Regional Sewer District" (2005)

Wisconsin – Milwaukee Metropolitan Sewerage District: Operation by United Water Services, Inc.

BACKGROUND

The Milwaukee Metropolitan Sewerage District (District) is a Wisconsin state-chartered, governmental agency providing wastewater services for 28 municipalities with a population of approximately 1 million. The District's chief responsibilities are to provide sewage treatment services and the maintenance and improvement of watercourses for all eighteen (18) municipalities within Milwaukee County (except the City of South Milwaukee) and sewerage treatment services for all or part of ten (10) municipalities in the surrounding counties of Ozaukee, Washington, Waukesha and Racine. While Milwaukee is the 19th largest city in the United States, its regional wastewater system is among the largest, most sophisticated and well run in the country.

In January 1998, the District entered into an agreement with United Water Services Inc. (UWS) for the management, operation and maintenance of the District's two wastewater treatment plants, biosolids management, field operations, and the watercourse drainage system. This agreement was for a 10-year term, commencing on March 1, 1998. The District's System is the largest wastewater treatment system under private operation in the United States. Under its contract and at the direction of the District, UWS provides the Operations and Maintenance (O&M) resources to operate the plants and manage the biosolids programs, including the allocation of biosolids to the different programs.

Wastewater treatment within the District's service area is provided at the two District-owned treatment plants. One is the Jones Island plant, which began operations in 1925. The other is the South Shore plant, which began operations in 1968.

In 1926, Jones Island was the first wastewater facility to recycle biosolids by producing an organic fertilizer known as Milorganite®. This commercial fertilizer is sold throughout the United States and Canada for home garden and lawn care as well as for golf courses, country clubs and other professional grounds. Sales of approximately 41,500 dry tons of Milorganite® in 2006 generated approximately $5.85 million in net revenues for the District.

Jones Island Wastewater Treatment Plant

Located on a peninsula in the Milwaukee harbor, Jones Island is the oldest operating activated sludge plant in the country. Because of its historic leadership in wastewater treatment, the facility has been designated a National Historic Civil Engineering Landmark by the American Society of Civil Engineers and has been placed on the National Register of Historic Places.

Jones Island was originally constructed in 1925 with a capacity of 85 million gallons per day (MGD). Expansions in 1935 and 1952 increased its treatment capacity to 200 MGD. With the completion of the Water Pollution Abatement Program (WPAP) in 1994, the daily maximum design flow and the peak (hourly) design capacity at Jones Island for full secondary treatment are approximately 300 MGD and 330 MGD, respectively. The full capacity with 60 MGD in-plant blending is 390 MGD. Current average daily flows to Jones Island are 112 MGD.

Wastewater treatment at Jones Island consists of preliminary/primary treatment, secondary treatment, phosphorus removal, disinfection and dechlorination, including screening, grit removal, primary settling, activated sludge stabilization, secondary settling and disinfection. Primary solids are generally pumped to the District's South Shore plant to undergo anaerobic digestion while secondary and anaerobically digested solids (from South Shore) are generally combined in the Dewatering and Drying facility for the production of Milorganite®, an organic fertilizer.

South Shore Wastewater Treatment Plant

Located to the south of Jones Island in Oak Creek, South Shore was constructed in 1964 as a primary treatment facility with a capacity of 60 MGD. The plant was expanded in 1974 to include secondary treatment and phosphorus removal. The design capacity of South Shore is 250 MGD Maximum Day and 300 MGD Maximum Hour. Current average daily flows to the plant are 100 MGD, mostly from the southern and western portions of the District's service area.

Sludge generated by the South Shore treatment process is either sent to digesters or pumped through the approximately 12-mile long interplant solids pipeline system to Jones Island for processing into Milorganite®. After anaerobic digestion, the stabilized sludge is either pumped to Jones Island for processing into Milorganite®, or it is utilized on agricultural sites as the organic fertilizer Agri-Life®, or it is sometimes hauled to a landfill. The District expects to discontinue the production of Agri-Life® in 2008.

Wastewater treatment at South Shore consists of preliminary/primary treatment, secondary treatment, phosphorus removal, disinfection and dechlorination, including screening, grit removal, primary settling, activated sludge stabilization, secondary settling and disinfection. Primary solids are generally processed in anaerobic digesters before which they are either pumped to Jones Island to supplement the production of Milorganite® or utilized as Agri-Life® as part of the District's agricultural biosolids programs. Secondary solids are generally pumped to Jones Island to supplement Milorganite® production.

Interplant Solids Pipeline System

The Interplant Solids Pipeline System is used to transport solids the 12 miles between Jones Island and South Shore plants to maximize efficient use of solids for anaerobic digestion and the production of heat-dried biosolids. The Interplant Solids Pipeline System consists of four (4) pipes: two (2) pipes at 12 inch diameter and two (2) pipes at 14 inch diameter, approximately 12 miles long and other interconnecting structures.

SELECTION OF RECYCLING AND DISPOSAL PRACTICE

The District produced a total of approximately 41,000 dry tons of biosolids in 2006. As has been the historical practice, the greatest percentage of that total has been converted to the heat dried biosolids product known as Milorganite® that is distributed and marketed in bulk or as packaged product for retail and professional sale throughout the United States and Canada. Most of the remainder of the biosolids has historically been beneficially reused as part of the District's agricultural land application programs (Agri-Life®). Only by exception under rare circumstances generally related to storage issues and time of year has there been a small quantity of biosolids disposed of in landfills.

The District uses two approaches to reduce the amount of pollutants discharged. The first approach is treatment at the two treatment facilities. This approach applies to suspended solids, pollutants that are biodegradable, and nutrients such as Biochemical Oxygen Demand (BOD), nitrogen, phosphorus, and pathogens. The second approach is through a source reduction program referred to as the Pretreatment Program, the primary focus of which is to treat wastes at their industrial source before they are released to the District's sewerage conveyance system.

Following is the summary of the District disposal options utilized for its biosolids in 2006 as reported in dry tons:

Milorganite®	Milorganite® Off-Spec Land Application	Milorganite® Off-Spec Landfill	Agri-Life® Liquid Agricultural Land Application	Agri-Life® Cake Agricultural Land Application	Agri-Life® Cake Landfill
31,700	2,500	100	2,400	4,200	200

ECONOMIC INFORMATION

The costs of operations based on 2006 budgets and costs are as follows:

- Typical proportion of sewerage operation costs attributable to sludge are 11.7% Capital and 56.8 % Operations & Maintenance (O&M):

- User charge to customers for treatment of sewage per 1,000 gallons: $0.948940
- One decatherm of natural gas: $5.3819
- One kilowatt hour electricity: $0.03305

DISTRIBUTION AND MARKETING (MILORGANITE®) OPTION

Including some carryover of 2005 inventory the District sold 39,100 dry tons of Milorganite® in 2006. The product was sold through a broad distribution and marketing network as bulk or in packages for professional and retail markets throughout the United States and Canada. Net revenue for the product was $5.85 million. Milorganite® is used widely as a turf and garden fertilizer in the retail market by the general public and professionally on golf courses.

Distribution and marketing of Milorganite® is permissible by virtue of the fact that this biosolids product meets the following three comprehensive standards as established by the United States Environmental Protection Agency. By meeting all three of the requirements below Milorganite® meets "Exceptional Quality" standards defined by the EPA and Wisconsin to allow unrestricted land application of biosolids.

1. Pollutant concentrations (As, Cd, Cu, Pb, Hg, Mo, Ni, Se, & Zn) for "High Quality" limits are met or exceeded.
2. Class A pathogen standards are met or exceeded.
3. Product is dried to greater than 90% Total Solids.

Milorganite® has long been marketed as a fertilizer with a guaranteed 6-2-0 analysis (based on NPK: Nitrogen-P_2O_5-K_2O). Milorganite® also has 4% Fe guarantee. Product that does not meet the District's guarantee for nitrogen, iron, or possibly particle size distribution may be disposed of as "off-spec" product. Nitrogen and iron guarantees are critical since the Milorganite® product is licensed and labeled for sale based on the above levels. Particle size distribution is important because the Milorganite® application guidelines are based on size of particle and the rate at which the product will be discharged from standard fertilizer spreaders.

Since late 2005, biosolids production within the District's system has been reduced by about 15% in large part because of the loss of a large industrial contributor of solids and BOD to the system. With that loss the demand for Milorganite® outpaced production in 2006. The District was able to take advantage of carryover inventory from 2005 to meet those needs.

In conjunction with other recent long term facilities planning, the District has also conducted a marketing study that showed that there should continue to be a viable annual market for more Milorganite® than was actually produced in 2006. Moreover, this study showed that the market, especially at the retail level, would be unaffected by a reduction of the nutrient analysis from 6-2-0 to 5-2-0.

Therefore by late 2007, the District began a transition toward production of a 5-2-0 Milo product. Having at least a portion of the annual Milorganite® production with a 5-2-0 guaranteed analysis enables the District to utilize much more of the typically lower nitrogen quality biosolids from the South Shore plant. Given the revenue potential of Milorganite® products and the uniquely complex energy budget associated with the heat drying facilities at Jones Island, it is advantageous for the District to manage biosolids in a manner that maximizes heat drying of the product. For this reason, the District is planning for the elimination of its Class B biosolids programs after 2007. However, the District plans to beneficially reuse any 'off-spec' Milorganite® production through an agricultural application program whenever possible.

AGRICULTURAL LAND APPLICATION

Agri-Life® is the name adopted by the District for the liquid anaerobically digested biosolids produced at the District's South Shore Wastewater Treatment Plant. In existence since 1975, the Agri-Life® program was implemented because the South Shore plant did not have facilities for heat drying biosolids and the Interplant Solids Pipeline (ISP) system did not yet exist. Since that time, the construction of the ISP in about 1990 allowed for the transfer of sludge to the Jones Island Wastewater Treatment Plant to supplement Milorganite® production. The transfer of solids between the plants has become integral to the management of Milorganite® production and biosolids system wide.

Also added to the South Shore plant in the mid 1990s was a plate and frame filter press facility. This facility has the capability of using polymer for dewatering liquid Agri-Life® from an average solids concentration of 8% to about 30% solids for filter cake. Given transportation costs and an average one-way haul distance to agricultural land of more than 40 miles, UWS has gradually diverted the production of solids at South Shore toward the production and utilization of filter cake. However, through 2006 the program continued to utilize a combination of liquid and cake. Farmer support for both product types has been favorable among the agricultural communities surrounding the Milwaukee metropolitan area.

In 2006, 2,400 dry tons of liquid Agri-Life® and 4,200 dry tons of filter cake were land applied. The liquid is applied via injection directly into the soil plow layer. The filter cake is applied using agricultural manure spreaders followed immediately by incorporation into the soil plow layer. Given nitrogen content of three to four percent an average of three to five dry tons of Agri-Life® is applied per acre only on land that has been permitted by the Wisconsin Department of Natural Resources. Typically, several thousand acres of land have been utilized for the Agri-Life® program on an annual basis.

Additionally, the District applied 2,500 dry tons of heat dried off-spec product from the Jones Island plant on agricultural land in southeastern Wisconsin. This product fell short of the 6% nitrogen guarantee still required in 2006 and therefore was unmarketable as Milorganite® but it met the standards of an Exceptional Quality biosolids as defined by the United States EPA.

As mentioned above, the potential market demand for Milorganite® exceeds the quantity produced in 2006. Therefore the District has considered the elimination of the Agri-Life® Class B land application program in order to divert virtually 100% of the biosolids through the Milorganite® production process.

LANDFILL

Landfill disposal for biosolids has generally been reserved as a backup option to be utilized only when beneficial reuse was not available. The relatively rare occurrence of events that might lead to the need for landfill disposal are typically related to seasonal weather conditions that inhibit the ability to land apply biosolids as, for example, during the winter, when frozen soil conditions prevent incorporation of the product.

As an emergency or long term outlet for biosolids should it be necessary, the District, through its private contractor, maintains contractual relationships with a local landfill. There are currently three large licensed municipal solid waste landfills on the perimeter of the District's metropolitan area that can be considered as viable landfills and that easily have the capacity to accept biosolids in the event the need arises.

INCINERATION OPTION

Incineration is not a practice utilized by the District. In long term facilities planning there is no consideration given to installation of incineration facilities per se.

GENERAL AGRICULTURAL SERVICE PRACTICE

The EPA federal regulations (40 CFR Part 503) promulgated in 1993 established the standards for land application of biosolids that were later (1995) incorporated into the state of Wisconsin code (NR 204). Both state and federal agencies have generally encouraged the beneficial reuse of biosolids. The District's own policies also favor beneficial reuse over options such as landfill disposal.

As part of the overall biosolids program management, the District has always met or exceeded all requirements of the regulatory agencies. Because Milorganite® is shipped well beyond the state of Wisconsin, the District also complies with regulatory agencies of all of the other states in the United States as well as with those in Canada. Compliance relates not only to the specific biosolids quality standards required under the various codes but also the frequency of sampling and the reporting of analyses as required.

Following are the average values for those pollutants regulated under the EPA code for the Milorganite®, Agri-Life®, and Agri-Life® filter cake from 2006:

Pollutant	Ceiling Concentration (mg/kg)	High Quality Limit (mg/kg)	Milorganite®	Agri-Life®	Filter Cake
% Solids	N/A	N/A	94%	8.3%	26%
Arsenic	75	41	8.4	15.3	16.3
Cadmium	85	39	3.9	4.1	4.1
Chromium	—	—	289	359	375
Copper	4,300	1,500	266	457	430
Lead	840	300	57	104	105
Mercury	57	17	0.3	1. 2	1.2
Molybdenum	75	—	11	19	20
Nickel	420	420	32	48	48
Selenium	100	100	4.4	7.6	7.9
Zinc	7,500	2,800	534	1,073	1,077
pH	N/A	N/A	6.2	7.2	8.1
Total N	N/A	N/A	5.8% dw	4.0% dw	3.4% dw
P_2O_5	N/A	N/A	4.35% dw	4.03 % dw	4.16% dw
K_2O	N/A	N/A	0.43% dw	0.19% dw	<0.1% dw

All of the District's Milorganite® products and off-spec heat dried biosolids that do not meet the nutrient requirement for Milorganite® still meet Class A standards as specified by the state of Wisconsin for pathogen content. Class A is defined as less than 1,000 Most Probable Number (MPN) per gram of Total Solids (TS) for fecal coliforms. Virtually all samples indicate a no detect level of fecal coliforms for heat dried products.

The District's Agri-Life® biosolids products are all classified as Class B based on those standards specified by the state of Wisconsin for pathogen content. Class B is defined as less than two million MPN/gTS. Use of Class B biosolids on agricultural land involves management practices that include specific limitations as to where the biosolids are applied, what crops are raised on the site, depth to high groundwater, slope, proximity to surface waters, wells, and residences, etc.

On an annual basis, the District also analyzes its biosolids products for a wide range of chemicals and compounds included in what is referred to as the priority pollutant scan. Also being monitored through 2006 on a regular basis were polychlorinated biphenyls (PCBs) and dioxins and furans. Product has never been distributed in the marketplace that exceeded allowable limits for PCBs or the other organic compounds.

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Livebottom unloading at ag site. Photo © Metrogro/Nikki Stefonick


43

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Commission d'épuration des eaux usées du Grand Moncton

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