Fecal Sludge Management in Developing Countries

A planning manual

Florian Klingel, Agnès Montangero, Doulaye Koné, and Martin Strauss

1st Edition, April 2002

Swiss Federal Institute for Environmental Science and Technology
Department for Water and Sanitation in Developing Countries

Foreword

This manual has been produced by SANDEC, the Department of Water and Sanitation in Developing Countries, which is part of the Swiss Federal Institute for Environmental Science and Technology (EAWAG).

The main principles for strategic sanitation planing have been adopted from the guide “Strategic Planning for Municipal Planning” from GHK Research and Training Ltd. SANDEC has carried out a case study of fecal sludge management in order to enlighten the issues specific to planning of fecal sludge management. This study took place in the City of Nam Dinh, in Vietnam. The corresponding study report “Septage Management Study Nam Dinh” has been issued by SANDEC and the Nam Dinh Urban Development Project (funded by the Swiss Agency for Development and Cooperation).

This manual is a first approach to provide guidance on strategic planning of fecal sludge management. It is intended to further develop this manual. Therefore SANDEC will highly appreciate your comments and suggestions on the manual.

For further information and comments, please contact Mr. Martin Strauss at:

Swiss Federal Institute for Environmental Science and Technology (EAWAG)
Water and Sanitation in Developing Countries (SANDEC)
Management of Sludge from On-site Sanitation Facilities (SOS)

P.O. Box 611
8600 Duebendorf
Switzerland
E-mail: Strauss@eawag.ch

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Glossary

Biosolids	The solids fraction of fecal sludge or of sewage sludge, which is biochemically stable and hygienically safe and, hence, can be used in agriculture as a soil conditioner and fertilizer.
Composting latrine	Latrine designed to receive both feces and vegetal matter with the aim of reducing moisture content of the waste and to achieve a carbon to nitrogen ratio that encourages its rapid decomposition. Note that "composting" is a misleading term, because thermophilic composting with pathogen destruction does not happen in composting latrines.
Fecal sludge	Sludge removed from all kind of on-site sanitation systems such as septic tanks, bucket latrines, pit latrines etc.
Septage	Fecal sludge from septic tanks (settled solids, scum and liquid).
Septic tank	A tank or container, normally with on inlet and one outlet, that retains sewage and reduces its strength by settlement and anaerobic digestion of excreta.

Abbreviations

BOD	Biochemical oxygen demand, unit for organic pollution
COD	Chemical oxygen demand, unit for organic pollution
FS	Fecal sludge
SANDEC	Swiss Federal Institute for Environmental Science and Technology, Dept. of Water and Sanitation in Developing Countries
STP	Sewage treatment plant
SW	Solid Waste
TS	Total Solids (dissolved + suspended solids)
TVS	Total Volatile Solids (ignitable part of TS)

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Photo record

All photos: SANDEC.

1 ABOUT THIS MANUAL

Why fecal sludge management?

In most urbanized areas in developing countries excreta are disposed off in facilities located on the housing plot itself. Whether these facilities are **septic tanks, dry latrines, bucket latrines, communal toilets, or other types, they all accumulate fecal sludge**, which needs to be removed periodically. If this sludge is not properly managed, negative impacts on the urban environment and on public health may result:

- **Environmental pollution** is caused by effluents of not regularly de-sludged septic tanks or community toilets;
- Large amounts of fecal sludge removed from sanitation facilities are **dumped indiscriminately into the environment** due to lacking disposal facilities;
- Fecal sludge is **used in unhygienic way in agriculture** because no sludge treatment is available.

All these problems can be **avoided by a proper management of fecal sludge**, which may include adequate de-sludging of sanitation facilities, safe handling and transport of sludge, treatment of sludge, and its safe disposal or reuse.

Figure 1: Dumping of fecal sludge in the outskirts of Ouagadougou, Burkina Faso

When is it important to plan fecal sludge management?

When inadequacy in sludge management causes problems

In absence of any orderly municipal sanitation planning, on-site sanitation facilities are most commonly developed by their users themselves. Those are little concerned about the problems with sludge removed from their facilities. Sludge management is usually limited to a de-sludging service that is provided by municipal agencies or the private sector, proper solutions for sludge disposal are generally lacking. This situation may have less serious impacts when the population density is low. However, in urban areas **the negative impacts on the urban environment become too high** and actions have to be taken. Instead of leaving the responsibility completely to individuals, the public relevance of fecal sludge management must be recognized and a strategy for better management of fecal sludge be developed.

When a comprehensive sanitation plan is being developed

Ideally, **fecal sludge management must be integral part of every sanitation plan**, which builds on on-site sanitation facilities. Sludge management is a indispensable part of the maintenance of these facilities. However, in reality sludge management is often neglected in sanitation planning because the need for it is less apparent than it is for the provision of water supply or toilet facilities. Even when a sanitation plan foresees a component for sludge management, its implementation is often impaired for the same reasons.

Sanitation planners and decision-makers must recognize the **importance of sludge management** whenever they deal with **on-site sanitation facilities**. It is for example irresponsible to promote septic tanks without providing in the same time solutions for regular de-sludging of the facilities and for safe disposal of the sludge.

On-site sanitation systems are often perceived as cheap in comparison to sewered systems, because the investment costs are covered by individuals and not by the public bodies. However, **fecal sludge management is an important cost factor**, which cannot be neglected and which has always to be taken into account when sanitation systems are planned.

What is the scope of this manual?

The present manual deals with one component of sanitation planning only**.** It is specifically meant for the case where **on-site sanitation facilities** are already existing, or are part of a sanitation plan. It explains how to manage the sludge produced from these facilities. The choice of the toilet facilities themselves and the **question of the overall sanitation system are not discussed** in this document. Abundant literature is already existing about general sanitation planning, however most with very little emphasis on sludge management. This document wants to contribute to close this gap.

Although this document concentrates on fecal sludge management, one should **never consider sludge management independently of the other components of a sanitation system**. Fecal sludge management is one component of a sanitation system, which has many repercussions on the other components and vice versa.

"Conventional" on-site sanitation includes facilities like pit latrines, communal pit or bucket toilets, flush toilets connected to septic tanks, etc. In these sanitation systems, feces, urine, and in some cases greywater are mixed and the sludge produced can be quite diluted. The efforts for sludge collection, transport and treatment are high, because the sludges are of important volume and difficult to handle. The present manual is **mainly designed for managing sludge from conventional on-site sanitation facilities**.

So called "ecological sanitation" is based on the minimization of waste at the source and its re-circulation into the natural cycles. Feces are kept separately from urine and water, and then dehydrated or decomposed in facilities such as double vault latrines, composting latrines and others. The aim is to transform the waste on-site in a product easier to handle, to treat and to reuse than sludge from conventional on-site sanitation facilities where feces and liquids are mixed. This manual may also be **helpful to plan the management of waste from "ecological sanitation" systems.**

Sewered sanitation transports feces, urine and toilet paper, diluted in large amounts of water, in sewers with self cleaning flow velocities. This type of sanitation produces no fecal sludge. However, in the case of sewage treatment, the handling of sewage sludge may require high management expenses too. Sewage sludge is usually even more problematic than fecal sludge from household toilet facilities, because it concentrates contaminants from industrial effluents. This document **does not treat management of sewage sludge.**

This manual is based on the results and the experiences of a detailed study of fecal sludge management in Nam Dinh City (200,000 inhabitants), in northern Vietnam. Therefore it is most **applicable for projects in middle-sized cities in Vietnam and other Southeast Asian countries**. We hope it may prove useful, though, in similar contexts in other countries and for larger cities too.

Who is this manual for?

This manual intends to provide practical guidance for the elaboration of fecal sludge management concepts, whether current problems with sludge management have to be solved or a future sanitation plan has to be established. It is mainly addressed to **environmental planners and engineers**, but will be useful as well **for politicians and decision-makers**.

And how to use this manual?

The manual is divided into two main parts: planning and tools. The **"planning" chapter contains the strategic approach of the planning process**. Step by step, the planning process is followed and the possible actions are explained. It is meant to be a checklist for what is necessary to do and which points are important to consider. The different steps will be accompanied by concrete examples from the case study in Nam Dinh.

The **"engineering tools" chapter contains a collection of detailed technical information** assisting the planning process. These engineering tools are essentially the result of SANDEC's research and development activities. The planner using this manual will certainly need other non-technical tools too, for instance for organizing workshops, developing institutional and financial solutions etc. SANDEC does not develop such tools because of its technical orientation. The last chapter therefore provides a list of useful sources covering important issues that have not been included in this manual.

2 PLANNING

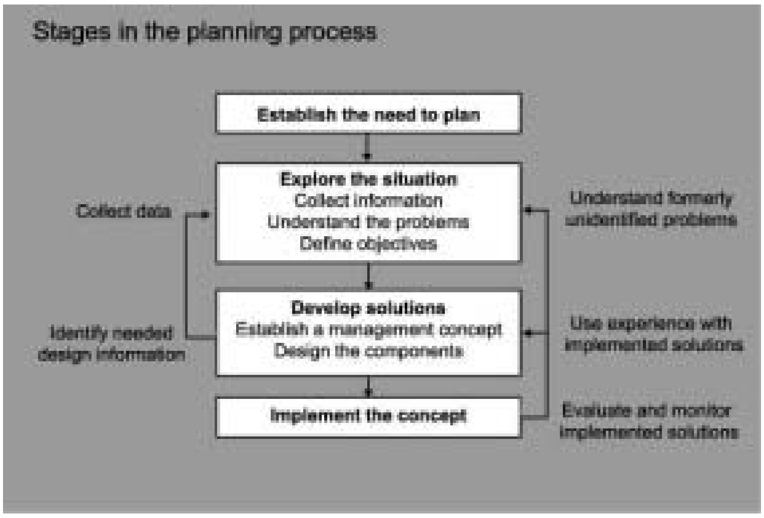
2.1 The process of planning

The planning process should follow logical stages. First a consensus about the need to plan has to be established among the involved parties. Then the situation has to be analyzed thoroughly to allow the identification of all existing problems and to define the objectives of improvement measures. The core piece of the planning process is to develop a future management concept. Finally the different components of this concept will be implemented.

It is very important not to consider the planning process as a one-way process. It does not end with its implementation. Experiences during planning and from implementation and operation should always be considered and plans be revised if necessary.

Figure 2 visualizes the different planning stages. The feedback loops illustrate the fact that plans are amended in the light of experience. During the elaboration of solutions, further need for information will be identified and this information then collected in a targeted way. The implemented components will be monitored and achievement of set objectives be evaluated. More precise information about adequacy of proposed solutions and about formerly unidentified problems will help developing better solutions.

Figure 2: Stages of the planning process, adapted from [2].



2.2 Establish the need to plan

The first step must be to develop a consensus on the need to plan fecal sludge management. No plan will work if those responsible for its implementation are not convinced of the need to plan. It is necessary to talk to the various stakeholders and, if necessary, to convince them of the benefits of fecal sludge management.

The main initiative for improvements in fecal sludge management is more likely to come from the authorities, than from the individual citizens. This is because the latter will not benefit directly of improved fecal sludge management, but more in indirect way, through a general environmental betterment. Therefore the support from authorities and decision-makers will be decisive for the success of better fecal sludge management. However, it is essential that the other stakeholders can agree upon the need to plan too.

☞ *Source of further information: [4] Annotated references on participatory approaches and communication for water and sanitation programming. [5] Methodology for participatory assessment with communities, institutions and policy makers.*

2.3 Explore the situation

2.3.1 Introduction

The thorough understanding of the existing situation is essential to tackle the right problems and to consider the right constraints while developing solutions. The first approach should be to gather a broad understanding of the situation and to know about all relevant issues and the relations between them.

Do not spend too much effort gathering technical data that may be of no practical use. Always ask yourself what you will do with the information you collect. The requirements for technical data will become apparent later, when specific solutions are envisaged.

Beside the basic goal of understanding the situation, you should always seek to identify the main problems with FS management and their causes.

Case Study Nam Dinh

The case study named “Septage Management Study Nam Dinh” was carried out in 2001 within the Nam Dinh Urban Development Project. This project, financed by Swiss and Vietnamese Governments, includes components for infrastructure development, public administration reform, community participation and economic development. The study aimed to provide a concept for septage management as part of the project’s wastewater management strategy. SANDEC participated in the study as part of their research mandate for fecal sludge management.

2.3.2 Explore the local context (geography, society, infrastructure)

A good knowledge of the general context around the specific problem is very important. This is especially valid if you are a representative of an external agency and not yet familiar with the local context.

The general conditions of the local situation set the frame within which potential solutions are possible. Basically, the planner should achieve enough knowledge of the situation to develop a good feeling for what is possible in the local context and what might be problematic.

Useful and easily available sources for information might be reports of projects located in the studied area and country reports issued by governmental or external agencies. Political, legal and institutional issues are best explored through various interviews with representatives of the different political levels and of discussions with persons outside these institutions. It is often necessary to be careful with official descriptions of these issues, as reality may look different. Environmental regulations for instance often have little effects on practice due to lacking awareness and enforcement.

Nam Dinh - The general situation

- **Geographic and socio-economic**

Nam Dinh is situated in Northern Vietnam, in the Red River delta. The climate is tropical and flooding of the city after torrential rainfalls is frequent due to the flat topography.

The city of Nam Dinh has a population of about 230,000. The economy of the province is still largely based on agriculture (rice), whereas the city functions as local center for administration, industry, service and trade. The overall growth of the population in Nam Dinh City with an estimated 1.25 % per year is very low, caused by falling birth rates and a steady migration flow to Hanoi. The average monthly income per person is 50 USD.

- **Public services**

Three public companies provide public services for water supply, fecal sludge and solid waste collection and disposal, and maintenance and cleaning of the drainage system. All have general weak capacity, including low staff skills, inadequate information systems and accounting procedures. Financial capacity is very limited, revenues are insufficient to meet the operational cost, and capital investment in new equipment or facilities remains low.

- **Sanitation infrastructure**

On-site sanitation is prevailing. The drainage system, conceived for the evacuation of storm waters, de-facto acts as a combined sewer system for both domestic wastewater, industrial wastewater and storm water. Domestic wastewater pretreated in septic tanks or greywater cannot infiltrate due to low soil permeability, and sooner or later ends up in the drainage system. The drainage system is not a closed system but is connected at numerous points to the irrigation system and to fishponds. The health risks through spreading the pathogen organisms and worse the industrial wastewater in the environment are high.

Roughly 60 % of the domestic solid waste is collected and disposed off on a new landfill. The landfill is sealed with a clay layer and is equipped with a basic drainage system for leachate extraction. Stabilization ponds are foreseen for leachate treatment.

Geography

Geographical factors such as topographical situation, geology or climatic conditions may have considerable influence on sanitation problems. They are major constraints influencing the feasibility of technological and organizational solutions.

Socio-economic situation, health and cultural aspects

Socio-economic and cultural aspects tell about the populations' ability and willingness to contribute or to accept proposed measures. It is very useful to assess the situation and potentials of private entrepreneurship in provision of public services. Health data may indicate problems related to sanitation and how urgent it is to solve them.

Political and legal framework

Good knowledge of the political system, the administration system, planning procedures etc. is essential for a planner. Legislation concerning environmental and construction issues, including discharge standards and construction policies need to be taken into account when planning treatment and disposal facilities.

Sanitation infrastructure and services

Wastewater management, solid waste management, urban drainage and other environmental and sanitary services are closely related to FS management, or they could be so in future. Public utilities or private enterprises are responsible for the provision of those services. It is important to know what are the different enterprises' activities, how the enterprises are organized, what are the available human and financial resources, and how are they equipped. Cost-recovery of services or the percentage of subsidizing are other important issues to explore. It is essential to know how responsibilities for the different services are shared among the different enterprises, which enterprises are involved in FS management, and which are their weak points in management.

A good overview about the existing infrastructure like toilet facilities, sewers and drains, treatment facilities, disposal or dumping sites, should be achieved. Find out what are currently the sanitation problems of highest priority, and how are they connected to problems related to FS management.

Existing plans

The different municipal or state departments and the public utilities may already have their own plans dealing with sanitation and fecal sludge management. These plans should be taken into account when preparing a new plan. Try to find out about the strengths and the weaknesses of existing plans. Pay particular attention to the way in which these plans deal with operation and maintenance and their financing. It is very useful to explore how earlier plans have been implemented or why they have not been implemented.

Land availability

The construction of facilities for FS management, e.g. for sludge treatment or storage will require land. It would be useful to have at early planning stages an overview on the general availability of land for this purpose, and on the cost or constraints of the land acquiring processes. Try to find out if the municipality already possesses land potentially suitable for sludge treatment, and what are the local constraints on these sites regarding accessibility, possible odor emissions or wastewater discharge.

2.3.3 Explore the situation of fecal sludge management

The next step must be to find out more in detail about the current and the expected future situation of FS management and all aspects that are related to it or may influence it.

Toilet facilities

Knowing the distribution of the various types of toilet facilities helps estimating what kind of fecal sludges you have to deal with. Don't assume that the distribution of different sanitation systems is stable, the situation may be quite dynamic, with some systems replacing others.

Nam Dinh - The situation of fecal sludge management

- **Toilet facilities**

Excreta disposal in Nam Dinh is based on on-site sanitation facilities in individual houses such as bucket latrines, pit latrines, double vault latrines, pour-flush or WC toilets connected to a septic tank.

The construction of septic tanks has started only in the late eighties and then rapidly increased within the past years. 1997, the coverage was already 50 % with roughly 22,000 septic tanks, in the year 2010 the coverage will probably reach 90 %.

Bucket toilets were the second most important sanitation facilities in 1997. Pour-flush or WC toilets, mostly connected to a septic tank increasingly replace these systems. The increasing propagation of septic tanks is part of a generalized tendency observed all over Vietnam: more and more people can afford to build an own toilet in-house.

- **Sludge collection**

Septic tanks in Nam Dinh are usually emptied only when problems like blocking of the toilet occur. The owner mandates either URENCO (the public company providing de-sludging services) or privates with the emptying of the septic tank. URENCO does the work by its single vacuum tanker and charges 20 USD for the service. Private emptiers are workers of URENCO doing this as second job out of working time, bucket collectors or others. They evacuate the sludge manually with shovels and buckets, and dispose it nearby into the drains. As no statistics exist, it is impossible to assess the number of septic tanks emptied in this way. Approximately one third of the houses are located in narrow lanes, out of the range of the vacuum tanker.

Bucket toilets and many public toilets are emptied by private collectors in daily to weekly intervals. These collectors are either farmers or intermediates selling the sludge to farmers for fertilizing purpose.

- **Disposal and reuse**

No assigned disposal point exists. Septage is dumped in fishponds, on fields or wherever the driver of the vacuum tanker finds a location to dump it. Sometimes the sludge can be sold to a farmer, but generally the money is not worth the effort necessary to find a person willing to take a load. Bucket sludge is very welcome by farmers practicing aquaculture as well as in agriculture. However, it is becoming increasingly unavailable and more expensive, due to the replacement of bucket latrines by septic tanks.

- **Potential for reuse of treated fecal sludge**

Following the National Institute for Agronomic Science in Hanoi, the lack of organic fertilizer in rice cultivation is a limiting factor for rice production in the Red River Delta. Compost from solid waste or treated fecal sludge is currently not traded, but all farmers state that such a product would be very welcome if price and effectiveness were satisfying.

It might be rather difficult to obtain exact figures about the distribution of different toilet facilities and the on-going developments. The best sources of information are usually household surveys where a statistically representative number of households are questioned about their situation regarding sanitation infrastructure, habits and awareness. Conducting such a survey is, however, a major exercise, which can rarely be justified for the purpose of FS management only. If no data from earlier surveys is available, you will need to conduct a smaller, “qualitative” survey by the mean of key interviews. It is not of primary importance to have at hand statistically significant data. Rather you should try to obtain, with a reasonable input of time and resources, a realistic picture of the current situation and the main tendencies.

A large household survey is usually conducted when a city wide sanitation plan, comprising overall sanitation, not FS management only, is going to be developed. In that case, the large number of information, which can be collected from the household questionings, justifies usually the high expenses for a large survey in the inception phase.

FS collection

The removal of sludge from toilet facilities, and the transport to the site of treatment or disposal, is the first important component of FS management. You need to understand well the current practice and what are the problems with it.

Who is collecting the FS - a municipal agency, private companies, individual entrepreneurs, farmers, or others? Why the facilities are emptied - on demand of the owners, on initiative of the authorities? How they are emptied - manually, or by vacuum tanker? How frequently they are emptied? How is the collection financed - by fees for the households, or by municipal subsidizes? How much is the fee? How much is the actual cost for the collection? What are the problems with FS collection - are facilities difficult to access, are the fees too high? Are transport distances a problem? These and more questions need to be answered to get a good picture of the situation.

The best way to get a complete impression on how is working the FS collection is to talk to the implicated persons. Don’t limit the interviews to municipal officials. Ask as well the workers of municipal agencies, householders, private FS collectors and so on. Very useful is to visit several households and to accompany the workers on a few collection tours.

Figure 3: Traditional fecal sludge management in China: Buckets from bucket latrines are collected by private entrepreneurs and sold to farmers, the fecal sludge is then diluted and used untreated for crop fertilizing.

FS treatment, disposal or reuse

The second main component of the FS management is what is being done with the sludge after collection from the facilities. The sludge may be disposed off, or used in agriculture, untreated or after having received a treatment.

How the sludge is treated, disposed off or used is best found through interviews with the agencies or individuals that are carrying out the collection. Observation of the disposal, treatment or reuse and visiting corresponding sites is essential. Be aware that the sludge may be treated, disposed or used in different ways, depending on the sludge type and who collects it. For example, if there is a municipal agency and individual entrepreneurs active in emptying toilets, the former may use a specific dumping site, whereas the latter may dump sludge into the drainage channels, or sell it to farmers.

It is important to analyze the existing treatment, disposal or reuse system on its strengths and weaknesses. Where are the main problems? Which components work well and should be preserved? Try to understand the money flow: How is treatment or landfilling is financed? Are farmers paying for fecal sludge?

Finding out what actually happens with the sludge is a crucial point, because it's there where most of the environmental pollution and health risks are generated.

Lessons from neighboring cities

It may be very helpful to visit a few neighboring cities to get informed about the situation of fecal sludge management in similar places. You may find situations where fecal sludge is managed in a much more satisfactory way, and get precious indications how you can solve the problems on your location. You may also find similar problems in similar contexts and though get confirmed the results of your only analysis.

☞ *Sources of further information: [3] Social survey methods. [4] Annotated references on participatory approaches and communication for water and sanitation programming. [5] Methodology for participatory assessment with communities, institutions and policy makers.*

2.3.4 Explore stakeholders' needs and perceptions

Any solution works best if it satisfies as far as possible the interests of all involved stakeholders, if everybody has a benefit through improvement of his individual situation or through incentives provided for motivation purpose. Proposed measures are most successful if they are able to solve the actual problems of all involved.

The above makes clear that it is indispensable to consider the perceptions, the needs, the interests and the personal situation of all involved stakeholders. Therefore you have to identify the stakeholders, all persons, groups or institutions who are directly or indirectly involved in FS management, and you have to talk to them.

Exploring the stakeholders' perceptions should not stand alone, but go along with exploring the general situation and the practices of FS management. The most valuable sources of information about the FS management situation are the involved stakeholders. You will have to talk to them to learn about the facts, but in the same time you should ask them about their personal point of view, situation and interests.

The most effective way to get representative information is to choose a number of persons who all belong to the same group of stakeholders but have different positions within this group. For example if you want to know about the situation of a municipal service agency, talk to the director, to administrators, and to several workers. If you want to know the problems of toilets users, ask people from different city neighborhoods and people using different toilet types. Try to find those who know most and who are most likely to tell what they know. Be always aware that the statements are very subjective and may be incomplete for one or the other reason.

The following list gives possible stakeholders and their role in FS management. The list may be not complete; you will find different stakeholders depending on every different situation.

Householders

The householders are the ones using the toilet facilities in which sludge accumulates. Usually it's them who decide about the type of toilet facility they build, about the time when they empty the toilet, and it's them who have to pay for the emptying. They know best who actually empties their toilet, what is the real price for it, and what are the technical problems with the emptying. Also if shared or public toilets are used, the householders, as their users, are able to provide corresponding information.

You should interview a number of people from different social classes, in different neighborhoods, and with different sanitation facilities. Best is to visit them at home, see their facilities and talk about their experience and problems with the emptying. Try to find out about their awareness for environmental and health issues, and about their attitude towards possible changes with the emptying regime.

Always keep in mind that the possible improvement measures need to be supported or at least tolerated by the individual citizens. You should find out what are important aspects for them, and where they might be lacking of knowledge to understand the necessity of improvements. This may provide hints as to future needs for public awareness and promotion activities.

A further important issue, which can be clarified through talks to individual citizens, is the cultural attitude towards the handling of human waste and the acceptance of use of human waste for fertilizing of food crops.

Figure 4: Interview with householders: Having a tee and talking about toilets in Nam Dinh, Vietnam.

Community based organizations and non governmental organizations

There might by various groups being active in the sanitation and health sector of the project area. These groups can be a valuable source of information representing the community in which they are active, as they are well informed about the needs and concerns of the community. On the other hand, these groups may facilitate the access to the community, for example if you plan awareness raising campaigns or household surveys.

Authorities

It is important to first identify all agencies potentially involved in the planning of FS management. These might be the local government or specialist governmental agencies on municipal, provincial or state level, responsible for planning, public services, construction, health, environment, etc. Understand which agency is responsible for which issue, and how responsibilities may interfere or where they are not clearly defined. Get informed about the habitual procedures for decision making.

In the particular case of fecal sludge management, the initiative for citywide planning has to come from the authorities. Therefore you have to explore how much the authorities are aware of the existing problems, and if necessary, you have to make them understand the need for actions. Try to make sure to have their continuous support for the planning, and keep them informed about your work.

Public utilities

The opinion of the people doing the daily business of FS management is very valuable and cannot be neglected while searching for improvements. Talk to representatives from all utility enterprises which are currently active in FS management, or which could be involved in future. Important is, again, to talk to persons from different hierarchic levels, from the director to the workers. Does the director think his enterprise has sufficiently support by the municipal government? What do the employees of the utility enterprises think are the main problems for their enterprise and for the provision of an adequate service? Try to get a feeling for the real interests of the people. For example: how do the workers earn their main income – through the salary paid by the enterprise, or do they earn money by emptying toilets on their own account, or by selling the sludge? Always try to find out by what mean the workers could be motivated to act in the desired way. For example: is it necessary to provide incentives to make sure that the driver of a vacuum tanker will take his load to the treatment plant rather to sell it to a farmer or to dump it on the next possible spot?

Private sector

The private sector active in FS management can be represented by companies operating vacuum trucks or similar equipment, or by individual workers who usually empty the toilets with shovels. You should ask them similar questions as to the public utility enterprises. Learn how they earn money - by payment for the emptying, or by selling the sludge. Try to find out, what kind of motivation or incentives it would need to make them act in the desired way.

Whereas it should be no problem to contact companies, it may be difficult to actually find the individual entrepreneurs. You could find some of them through the householders by asking who has emptied their toilet. Be aware that private entrepreneurs might be at the same time employees of the public enterprises and do empty toilets on their own account as a secondary job.

Farmers

The farmers are the potential users of the treated fecal sludge. Exploring the current reuse practice will tell you a lot about the general and cultural attitude towards use of human waste in agriculture, about the current health risks, and about the potential for use of treated sludge.

One main point to explore must be the acceptance by the farmers of a product from sludge treatment. You should conduct a tentative market analysis. The main objective for interviews with farmers is to get an idea if treated FS, and how much of it, could be used in agriculture, how much the farmers would be willing to pay for it, and in which form they would prefer to receive the product.

Agriculture services and state agencies can also be a valuable source of information on this topic.

Figure 5: Interview with a rice-farmer in Nam Dinh, Vietnam

☞ *Sources of further information: [3] Social survey methods. [4] Annotated references on participatory approaches and communication for water and sanitation programming. [5] Methodology for participatory assessment with communities, institutions and policy makers.*
Useful tools: 3.2.1 Sludge sampling and analysis

2.3.5 Data collection

It will be necessary to collect more detailed data for the (pre-) design of components of the future management concept. This requires that you already are familiar with the situation, know about the problems, have defined the main objectives, and that you have already pre-selected several potential solutions. Therefore, the data collection does not follow directly the logical sequence of the other described points of the situation analysis. Remember that the planning process cannot be treated as a one-way process (see 2.1), that you should use the information collected in the initial stages to identify further needs for more detailed information.

The data you need can be of very different nature: a more detailed survey to know about the distribution of different toilet types; a thorough market analysis for a fertilizer from treated FS; a detailed analysis of a specific sanitation service; a meaningful sludge analyzing for the design of treatment facilities; etc.

Always try to maintain a reasonable balance between the expenses for the data collection and the benefit from it. Detailed data is not always much more useful than already available data from similar locations or even data from standard literature.

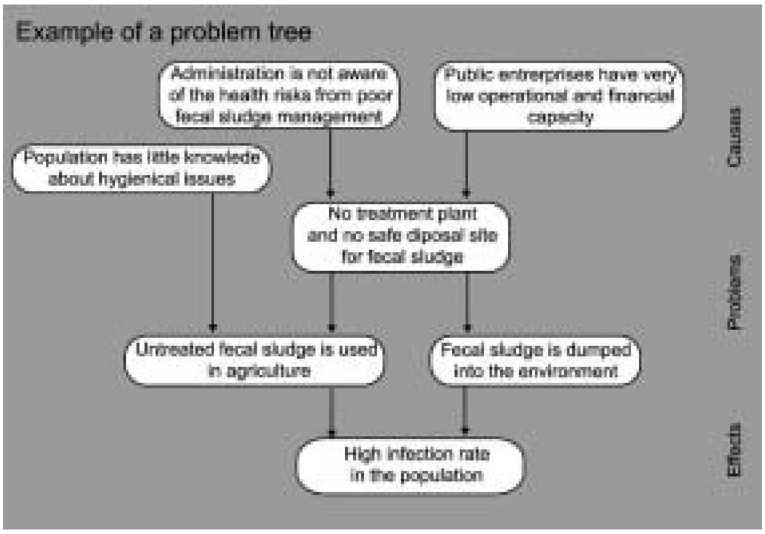
☞ *Sources of further information: [3] Social survey methods.*
Useful tools: 3.2.1 Sludge sampling and analysis.

2.3.6 Understand the problems

At this stage, you should have achieved a good understanding of the current situation with FS management and related sectors, you should be aware of the local constraints, and of the different perceptions of the implicated parties. You should be able now to identify the main problems of the current situation or the problems that are likely to occur in the near future.

It is not enough to identify the problems, but you should understand as well the causes of the problems. To solve problems you will need to understand how problems, causes and effects are linked. A good way to carry out problem analysis is to develop a problem tree, where you collect all problems and link them following their cause - effect relations.

Figure 6: The problem tree helps identifying the cause-effect relations



☞ *Useful tools: 3.1.1 Disease transmission through poor fecal sludge management.*

2.4 Develop the management concept

2.4.1 Planning principles

Involve stakeholders

The development of solutions should happen in close collaboration with all stakeholders. You should continuously seek for feedback from the involved parties, to find out if your ideas and propositions are acceptable and understandable to them, and to confirm if your propositions satisfy the real needs.

Stakeholder involvement during the planning process may be of variable intensity. You can limit yourself to work out components of the plan and to consult the stakeholders from time to time. You can organize planning workshops in several stages of the planning process, where all representatives come together and work collectively on decisive parts of the plan. A workshop may be organized for problem analysis and definition of objectives, where you present the results of your situation analysis, and seek for common agreement on problems, objectives and priorities. Another possible workshop could be organized for evaluation of options, where you present several previously developed scenarios, which are then discussed together. The most intensive form of stakeholder involvement would be the formation of a planning committee, where representatives of the different parties regularly come together to work out solutions. Which way you go depends on the project size, on the willingness to participate of the stakeholders and on other aspects. More intensive involvement of stakeholders may slow down considerably the planning process, however the chance that widely accepted solutions result are correspondingly higher.

Have a global vision – think about concrete measures

Developing the management concept means developing a vision how fecal sludge management could work citywide, and developing the individual components to be built up step by step. You need always to keep an eye on both, how an idea can be part of a whole, and how the idea can be concretely implemented in a small scale.

Appropriateness of measures and technologies

The paradigm of the appropriateness of measures and technologies has always to be respected while planning sanitation or fecal sludge management in the context of developing countries. The use of technologies and management concepts adapted to local conditions is of prime importance. All proposed measures must match with available human, technical and financial resources and have to be perfectly acceptable for the population and the authorities.

Make the plan sustainable

Ensuring to sustain improvement measures over time means to ensure that all involved stakeholders want to act in the sense of the plan, that they know how to do this, and that they are able to do it. Appropriate incentive systems can make sure that the stakeholders are motivated to act in the desired way. Information and training efforts are required to increase knowledge and skills of the involved persons. Sound finances are required to enable them to act in the desired way.

Make the plan official

Your concept for fecal sludge management will only be effective if the various organizations that are expected to implement it, recognize it as their plan. You should do everything that you can to have your concept accepted as the official plan for fecal sludge management of the town. Everything possible should be done to ensure that the agreed actions can be formally included in the programs and budgets produced by the various stakeholder organizations.

Figure 7: Appropriateness of technologies in Accra, Ghana:

Above a conventional sewage treatment plant (trickling filters and secondary clarifiers) that never operated.

Below a simple settling tank for fecal sludge treatment that is operating successfully.

☞ *Sources of further information: [2] Strategic planning for municipal sanitation – a guide. [4] Annotated references on participatory approaches and communication for water and sanitation programming. [5] Methodology for participatory assessment with communities, institutions and policy makers*

2.4.2 Define objectives and criteria

The first step of developing solutions is to define where you want to go. You have to define the main planning objectives, and to specify them, to set the targets for the various measures to be developed. The simple rewording of the identified problems will already

Nam Dinh - Problem identification, objectives and planning horizon

- **Main problems**

Risk for public health due to lacking treatment or safe disposal: Septage is handled without protection measures, dumped into the environment or used untreated in agriculture.

Solids accumulation in drainage system because of lacking maintenance of septic tanks: Septic tanks are often not emptied in the designed intervals. They become full with sludge and cannot retain the solids any more. Increased solids accumulation in the drainage system results, which contributes to blockage of drains and flooding.

- **Causes of the problems**

Municipality and population are not aware that septic tanks should be emptied more often to maintain their function.

The public enterprises have insufficient financial and operational capacity to improve septage collection.

There is no existing treatment facility or a safe disposal site.

- **Principal objectives**

Improvement of public health**:** Elimination of dumping of septage into the environment and of use of untreated septage in agriculture.

Improving the functioning of the drainage system*:* Enhancing solids retention in septic tank to reduce solids accumulation in the drainage system.

- **Time frame**

2 years**:** Collection capacity will be extended to 1000 septic tanks/yr by more efficient use of the already existing equipment. Corresponding treatment capacity will be provided. The plant for this first planning phase will be built as soon as possible (pilot plant).

5 years**:** Collection and treatment capacity will be extended to 4 times of the current capacity (4000 septic tanks/yr.). Design and proposed capacity of the treatment plant will be revised using the experience gained with the first phase plant.

deliver a more or less complete list of objectives, with the subordinated specific objectives.

In most cases, one overall objective will be “to improve public health”, the protection of the population from health risks through the transmission of pathogenic organisms contained in human feces.

Once the list of specific objectives established, you should develop clear criteria how these objectives are fulfilled. The proposed solutions can then be evaluated on their adequacy to achieve the set objectives by the help of those criteria. Clearly measurable indicators are helpful to evaluate the fulfilling of criteria.

2.4.3 Develop the time frame

The formerly established objectives have to be translated into a concrete schedule that defines the targets to be achieved in corresponding periods. For several reasons, it is advisable to proceed in rather small steps instead of trying one big move forward:

- Actions have to match with available resources. Too ambitious targets are unlikely to be achievable. It is more encouraging for all involved, if realistic goals can be achieved within the set period.

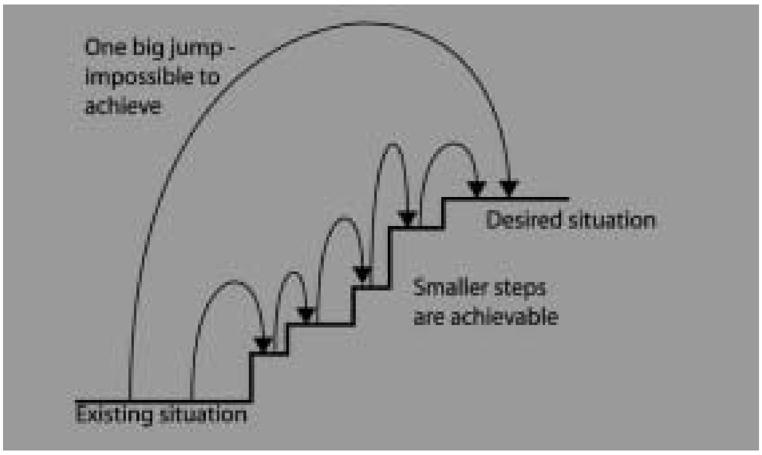
- Practical experience with proposed solutions should be collected, and used in planning, before solutions are introduced citywide.

- It is often very difficult to make precise projections of the demand for periods of 10 to 20 years, like it is habitual for facility design in industrialized countries. In developing countries, the data basis is often very imprecise and the situation is too dynamic to allow good predictions. Planning and implementation in small steps assures a higher flexibility to respond to the real demand.

Small-scale or pilot projects are more easily and quickly prepared and implemented with already available resources. In this way, you can achieve immediate improvements. In the same time, the experience with the first steps will help you to plan the further steps on a more precise data basis. Positive experiences will help to convince the stakeholders of the success of proposed measures, as you can directly show how it works.

Try to set realistic targets for short periods, such as one to three year periods. These targets should be, however, part of a global and more long-term concept that will be fulfilled step by step.

Figure 8: Several small steps are easier than on big jump, adapted from [2].



2.4.4 Design fecal sludge collection

Demand-driven sludge collection or planned sludge collection

In general, the vault emptying and sludge collection is driven by the demand of the toilet owners, and is financed by direct fees. This system usually works well and mostly there is no reason to change it. Both, public utilities and the private sector can provide this service.

However, in certain cases it might be impossible to leave the initiative for sludge emptying to the householders. This is especially the case when environmental problems are caused because sludge is not removed often enough. For example septic tanks may loose their removal capacity when too much sludge is accumulated, leading to considerable carry-over of pollutants into groundwater, drains and surface waters.

Introducing a planned sludge collection where the authorities take the initiative for emptying facilities in the households is a complex task. You will need a considerably increased management capacity of the service provider, comprising a detailed databank about the city's toilet facilities and their emptying dates, a good planning capacity, and the corresponding technical equipment. You will need to achieve the necessary understanding and the awareness of the householders for the duty to empty their facilities more often. You will have to think if you need a different fee system, which can motivate the owners to empty their facilities more frequently. And eventually you need to know if, and how you can include the private sector in a directed sludge collection system.

Improve hygiene when sludge is handled

Hygiene with sludge handling is usually an important issue when manual pit or vault emptying is common. The workers, whether independent or employees of private or municipal enterprises, are seldom aware of the health risks and may use no protection during their work.

You can follow different strategies to improve such a situation: The first would be to try replacing manual by mechanical sludge removal. This means at the same time that you will replace independent workers by companies, as only these can operate expensive mechanical equipment. The main difficulty will then be how to prevent the independent workers from doing their usual business and how to provide them with a new work.

The other strategy would rather be to accept the practice of manual removal and to promote more hygienic practices, such as the use of protection measures. Stricter rules and better enforcement concerning health protection of employees of municipal or private enterprises would be necessary too.

Assure that sludge is transported to the desired site

One major cause of indiscriminate dumping of fecal sludge is the lack of a disposal site. The collectors may dump the sludge in other sites or sell it to farmers, even if you are providing a treatment plant or a safe disposal site. Therefore you will have to make sure that the collected sludge actually reaches the desired site.

The most important aspect is that you have to locate the disposal sites in order that transport to this site is neither expensive nor uncomfortable. Additionally you may need to provide corresponding incentives to the workers, which motivate them to do what they should actually do. Often workers may earn more from selling sludge to farmers than from their salary. Workers also may dump the sludge as close to the area of collection as possible to be able to make additional collection tours on their own account. Indispensable condition that you can provide an effective incentive system is that you previously understood very well the actual ways in which the workers earn money and what motivates them.

Improve technical equipment and assure its operation and maintenance

Very common are technical problems with removal of sludge from sanitation facilities, such as inaccessibility of houses by truck mounted vacuum tankers. Many types of sludge evacuation pumps and vehicles have been developed for that kind of situation. To solve these problems is mostly a matter of providing funds for investment in new equipment.

Nam Dinh - Proposed improvements of septage collection

The recommended equipment for septage collection consists of classical vacuum tankers in combination with small hand-pushed vacuum tugs. These vacuum tugs allow accessing septic tanks located in very narrow lanes, which are today still emptied exclusively by hand. In this way, the public utility enterprise can extend its emptying service to all households.

Mini vacuum tug in Haiphong City, Vietnam

The main problems with septage collection are institutional matters. These sensitive issues must be discussed among decision-makers prior to the design of an effective septage collection system: Should frequent septic tanks emptying become compulsory? Should reduced monthly fees replace the high direct fees? How can the responsibilities of the public utility enterprises be better defined?

The introduction of a systematic septic tank emptying and of monthly fees in selected wards is recommended. In this way the septage collection rate can be increased considerably and the experiences of the new system can be used in the political discussions and the institutional reform process.

A very frequent problem in developing countries is lacking capacities for operation and maintenance of equipment. In many cases central government or external donors provide the funds for investment in equipment and facilities, but the projects fail because operation and maintenance has been neglected. It is therefore of prime importance to make sure that revenues from the services cover the costs for operation and maintenance. Think about arrangements on an efficient and reliable maintenance system at the service provider.

Whenever new equipment is being purchased or new operation maintenance procedures are being introduced, you have to make sure that staff receives sufficient training on the new equipment and procedures.

☞ *Source of further information: [8] Practical tools to achieve effective Operation & Maintenance.*
Useful tools: 3.1.2. How to cut the transmission pathways. 3.3.1 Technologies for vault or pit emptying and sludge haulage.

2.4.5 Design fecal sludge treatment

Provide an attractive disposal point

The first and main function of fecal sludge treatment is to get rid of the sludge. You want to offer a reliable disposal point, where no harm is created to the environment and public health. As already discussed under the previous point, you have to think carefully how to make the disposal point attractive enough to achieve that all sludge reaches the facility.

The most important factor is the location. You must avoid that transport costs for delivering sludge to the facility become too high. In the case of big cities with large distances and much traffic, you should probably favor several decentralized treatment facilities over one central facility.

Appropriate incentive systems should make sure that all collected fecal sludge reaches the plant. For example, rather than excluding private companies from delivering sludge to the plant, you should motivate them to do that. You will have to provide motivating incentives to the workers if the sense of responsibility within the enterprises is low, or the enforcement of corresponding rules is difficult.

When choosing the treatment sites, it is very important to take into account the resistance or acceptance of the population neighboring the site or the access roads. Possible negotiations for compensation measures should be held early in the plan. It is important to include surface for possible extensions of the plant and for buffer zones when purchasing or reserving land for sludge treatment.

Minimize impacts from treatment and treatment products

Products from a sludge treatment plant are in general odors, liquid effluents and dried sludge.

Odors are more a problem for the public acceptance than a real danger for health and environment. Nevertheless, this is reason enough to take the odor problem very serious. You can reduce odor emissions by choosing the adequate treatment technologies or by locating the plant at adequate distance from human settlements.

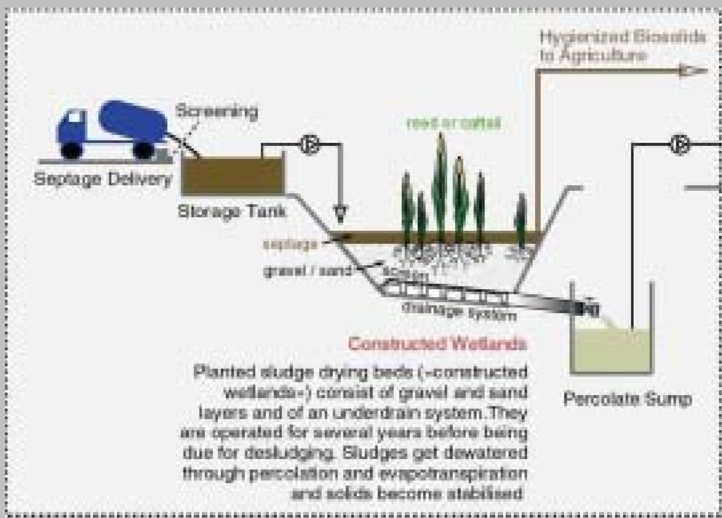
Agricultural reuse of the liquid effluent from sludge treatment is in most cases impossible due to the high salt content. Therefore, the effluent will usually be discharged into the environment and reduction of pollutant contents in the effluent is the main concern. Authorities generally apply wastewater discharge standards as sludge treatment objectives. However, it may hardly be possible to fulfill strict discharge standards with a reasonable technological input because fecal sludge has 10-100 times higher and much more variable pollutant concentrations than municipal wastewater. Nevertheless, treating the sludge prior to discharge will, in itself, constitute substantial health and environmental improvements, even if stringent effluent quality standards cannot be met. A pragmatic approach concerning effluent standards is, though, often very difficult. Officials may insist to apply wastewater standards because they are not familiar with fecal sludge and its specificity. A possible compromise may be to set a removal percentage rather than an absolute effluent concentration as treatment objective. For example, Ghana has applied a 90% BOD and fecal coliform removal standard for a sludge treatment plant in Accra [7].

The solid treatment product should at minimum have adequate moisture content (< 80%) to allow safe disposal on sanitary landfills. Ideally it should have adequate quality for agricultural reuse. Sludge to be used in agriculture has to be chemically safe and not contain disease-transmitting organisms beyond tolerance limits. Excluding high-tech treatments, complete pathogen destruction can only be achieved by thermophilic

Nam Dinh - Proposed septage treatment

A septage treatment plant is proposed. The chosen technology is dewatering and biochemical stabilization of septage in constructed wetlands. This treatment plant will transform septage in a solids fraction with greatly reduced volume and very low pathogen content, and in a liquid fraction suitable for discharge after treatment in stabilization ponds. Constructed wetlands have been chosen as the preferred option for Nam Dinh after a detailed evaluation of all available septage treatment technologies.

It is proposed to construct a first treatment plant with modest capacity on the site of the existing landfill. It is planned to treat the effluent from the sludge treatment together with landfill leachate. This plant has then to be closely monitored. The gained experiences and data will help to design the extensions of the plant for the next planning phase.



Proposed constructed wetlands treatment plant for Nam Dinh

Proposed agricultural use of treated septage

The solids produced from septage treatment constitute an excellent organic fertilizer. The commercialization of these “biosolids” is recommended, because it can generate revenues, save landfill space and supply Nam Dinh's agriculture with urgently needed soil-conditioner.

Intensive marketing efforts are necessary to achieve complete commercialization of the biosolids. Trials of efficiency of the fertilizer product should be carried out in collaboration with the provincial agricultural service. The agriculture cooperatives can be used for initial commercialization. The cooperatives could later act as local agent and inform farmers about the quality of the product.

composting or by storage over extended periods (½ to 1 year). Additionally, sludge to be used in agriculture has to be delivered in acceptable form to the farmers. You have to make sure that your product corresponds to what consumers wish. It would be favorable to locate the treatment plant close to the sites of reuse to reduce transport costs. However, the priority must still be to locate the plant close to the area of sludge collection.

Assure operation and maintenance of the plants

As already discussed for sludge collection equipment, you have to pay very much attention on operation and maintenance of the proposed facilities. Choose technologies that are adapted to the technological and financial means of the operator. Prepare for corresponding training of staff. Always keep in mind, that lacking operation and maintenance is cause number one for the failure of infrastructure projects in developing countries.

☞ *Source of further information: [8] Practical tools to achieve effective Operation & Maintenance*
Useful tools: 3.1.2. How to cut the transmission pathways. 3.2.1 Sludge sampling and analysis. 3.3.2 Technologies for fecal sludge treatment.

2.4.6 Design fecal sludge reuse or disposal

Reuse versus disposal

In general reuse of sludge should be preferred over disposal on landfill for several reasons:

- Commercialization of treated sludge can generate revenues
- No use of landfill space
- Fecal sludge, in contrast to sewage sludge has little chemical contamination and can therefore be considered as valuable resource, which should be valorized. In a long-term point of view, the recycling of waste is always the preferable option.

You should only consider disposing the treated sludge if there is no need and market for a soil conditioner, or if the additional expenses for providing a product suitable for agricultural use can not be justified. Generally, the disposal of treated sludge is not problematic, as long as the sludge is sufficiently dehydrated and a sanitary landfill is available.

Develop market for treated sludge

When you consider the commercialization of the treated sludge, you will have to spend sufficiently effort on developing the market for your product. You will have to identify potential customers and analyze their needs and wishes. You should develop the customer's confidence by proofing the benefits of your product, best in collaboration with an agricultural service or research institution. You have to find ways how to distribute the product and how to promote it. It may be very useful to use existent structures such as commercial fertilizer distributors or agricultural cooperatives. Never assume that the farmers just will come and buy treated sludge without any effort from your side.

☞ *Useful tools: 3.1.2. How to cut the transmission pathways. 3.3.2 Technologies for fecal sludge treatment.*

2.4.7 Define responsibilities, communication and co-ordination mechanisms

Define clear responsibilities

Who will do what in fecal sludge management? Each task should be very clearly assigned to one of the involved parties. Best is when you can assign the responsibilities in a logical way. For example one single municipal enterprise could carry out the sludge collection, operate the treatment facilities and trade the fertilizer product. In a context favorable to privatization of public services, these tasks could be assigned to different private companies, which are responsible to a regulatory agency. In most cases, however, you will have to be considerate of existing structures that are not easily changeable. Important is to avoid that conflicts about competencies and responsibilities can occur. Try as well to define clearly the role of other governmental organizations, of NGO's and of the community members. Everyone involved in fecal sludge management should know clearly what he is meant to be doing and with whom he needs to liaise.

Develop mechanisms for co-ordination

Lack of co-ordination between the different involved groups may be a very important problem. It may be advantageous to install a committee where all involved groups are represented. However, you have to make sure that one organization will be responsible for the leadership of this committee, and that the committee's decisions result into actions. It is essential that the committee's authority be mutually recognized, best through higher government levels too.

Don't forget that fecal sludge management is not an isolated issue, it is closely linked and interconnected to other sanitation issues. Co-ordination with the other sanitation services is therefore indispensable during all stages of planning and day to day running. The above mentioned committee should therefore best be a sanitation committee dealing with all aspects of sanitation, including fecal sludge management.

Develop mechanisms for communication

An ongoing dialogue and consultation with service users should become part of the routine of municipal service delivery. It may be best to assign this task to a third party such as an NGO that is skilled in community liaison. Again, communication with service users should not be limited to emptying of vaults and pits, but rather comprise all sanitation issues.

Raise public awareness

For not well informed people, the need for fecal sludge management is less obvious than the need for water supply and clean toilets. Nonetheless you will need the support of the householders for improvements of sludge management, because they will participate in its organization and financing. You should conduct awareness raising campaigns to ensure the acceptance of the your measures and to achieve changes in the behavior, favorable to better sludge management. Such behavior changes might be that people know that they should empty the vault of their toilets or their septic tank more often, or that they should not throw waste into the toilets, etc. Long lasting effects with awareness raising are best obtained when promotion activities are institutionalized (e.g. hygienic education in schools).

In many cases, you will need as well to awake the necessary awareness within the authorities and service providers.

☞ *Sources of further information: [4] Annotated references on participatory approaches and communication for water and sanitation programming. [5] Methodology for participatory assessment with communities, institutions and policy makers. [9] Just stir gently – The way to mix hygiene education with water supply and sanitation.*
Useful tools: 3.1.1 Disease transmission through poor fecal sludge management 3.1.2. How to cut the transmission pathways.

2.4.8 Develop financial arrangements

Ensure sound finances

The management of fecal sludge can only be successful in a sustainable way when its financing is ensured. You have to pay very much attention to find stable arrangements for covering running costs like salaries, operation and maintenance of equipment and facilities. As far as possible, the running costs have to be recovered from the service fees or revenues. Dependence on external subsidizing should be minimized.

Possible sources of financing for FS management can be the fees collected from households, the municipal budget, and revenues from sludge commercialization or from selling of licenses to private enterprises. Funding from central government or external donors is generally limited to investments.

You have to think about a sound fee system, where fees sufficiently contribute to cost recovery, are acceptable for the service users, and can be actually collected.

Be careful not to overestimate revenues from sludge commercialization. You need to base your calculation on careful assumptions. This is especially true if the sold product is new on the market and no experience with the willingness to pay of farmers exists. Depending on the situation, it may be possible that you can generate revenues through licensing private companies for sludge collection, or through fees for disposal at the treatment site. In other contexts, however, fees for disposal a treatment site may be repelling and entrepreneurs may rather dump the sludge elsewhere.

Always make the implementation of new components of fecal sludge management dependent on available resources, both for investment and for operation costs. Better is to implement small-scale components, which actually work in a sustainable way, than to start too ambitious projects, which may fail soon due to lack of money for the day to day running.

Use financing as steering instrument

Financial arrangements are not only about absolute coverage of costs, but as well about intelligent ways how to use money for motivating workers to do what they are supposed to do. Some examples how to provide incentives in different components of FS management were already discussed earlier in this text. However, you will need to find an arrangement working for the whole chain of FS management. Try to get a clear idea where revenues are generated and whereto the money flows. It depends on the local situation, how you should then arrange the money flows to achieve best effects. Factors like the general sense of responsibility, the danger of corruption, the dependence of workers on additional income, etc., play an important role. As an example, you could make the workers participating at the income from sludge commercialization, which can motivate them to actually deliver sludge to the treatment plant and to operate the plant properly.

2.5 Choose technologies

Screen available technologies

When you start choosing the technologies for equipment and facilities, you should consider all available and commonly used technologies in an objective way. With a first screening, considering general criteria and obvious local constraints, you can already select a reduced number of potentially feasible technologies, without going too much into details. You should try to have at hand a small number of interesting options, which you will then develop more in detail to make possible a thorough evaluation.

Pre-design potentially feasible technologies

To make possible an objective comparison between different scenarios, you have to develop each scenario for the same situation, the same basic conditions, and for the same targets. For example you will compare treatment plants using different technologies, but all fulfilling the requirements for a certain planning horizon and for a set treatment goal. You will have to develop preliminary designs and operating schemes, to allow the detailed evaluation.

Evaluate the options

Once you have at hand several sufficiently detailed scenarios, you can evaluate them following previously established criteria. Try to define clear criteria and indicators relative performance, process reliability and cost of the examined technologies. Using the preliminary designs, you will have to establish estimations regarding expected performance, and investment, operation and maintenance costs. Try as well to predict how reliable the technologies will be at the given local conditions. The final evaluation can be done using a multi-criteria matrix, where you attribute to each scenario and each criterion a valuation. In this way you will achieve a very objective selection of the technologies, and you will have at hand a good data basis for further discussion with stakeholders.

☞ *Sources of further information: [1] Nam Dinh Septage management study. [8] Practical tools to achieve effective Operation & Maintenance*
Useful tools: 3.3.2 Technologies for fecal sludge treatment.

Nam Dinh - Criteria for evaluation of treatment technologies

A list of criteria has been established for the evaluation of potential treatment technologies. These criteria define how the fulfilling of treatment objectives by the different options will be measured.

Specific objectives for septage treatment

- Providing treatment capacity for 1000 septic tanks per year within 2 years.
- Transforming septage into products suitable for safe disposal or reuse

Performance criteria

a) Achievable consistency of solids. The solids should be easy to handle and the volume be reduced as much as possible. The parameter, which best expresses this, is the achievable solids content. TS > 20-30 % should be achieved.

b) Hygienic quality of solids. The content of viable pathogens (worm-eggs) should be very low or zero to allow safe reuse in agriculture. The requirement for post-treatment to meet this criterion should be minimal.

c) Quality of liquid effluent. The content of pollutants should meet the Vietnamese standard regulating discharge in surface waters.

Criteria regarding simplicity and reliability of process

d) O+M requirements. The process should require as little input as possible to operate and to maintain it.

e) Skills required for operation and supervision. The skills required to operate the plant should be as basic as possible.

f) Risk of failure: The estimated risk of failure through identified weak points should be as low as possible.

Cost criteria

g) Minimal Land requirement.

h) Minimal Investment costs

i) Minimal Operation and maintenance cost

2.6 Implement the concept

Implementation is part of the planning process!

The implementation should not be seen as the final stage of the planning process. You and the stakeholders will learn a lot from the process of implementation and you should use the learned lessons for future initiatives. This principle should be institutionalized through fixed procedures for monitoring and evaluation of the implemented components and for the use of the gained information before implementing further components.

Figure 9: Learning from existing facilities and pilot plants: Sampling from a settling tank in Accra, Ghana

Prepare proposals

For each component, you will have to prepare proposals and have them adopted for implementation. For physical facilities such as a treatment plant, you will have to prepare technical designs, drawings, estimates and contract documentation. For procurement of equipment such as vacuum tankers, you will have to prepare detailed tender documents, including components for training of staff. Proposals for components depending on human resource input such as training programs or awareness campaigns should clearly define who is going to do the work, how it will be financed, and how it will be linked to other components. Be aware that procedures of adoption and tendering can take a lot of time.

Implement components

Responsibility for carrying out the work for treatment facilities will usually be awarded to a conventional contractor. If possible you should divide the work in relatively small packages, which can be handled by smaller local contractors. This has the advantage of better competition between contractors and that it helps to build local capacity. Good supervision is very important to ensure the quality of work provided by contractors. If possible, good work should be rewarded and supervision staff and implementing organizations held to account when the quality of work is poor. One way to ensure that this happens is to involve people from the benefiting communities in the supervision of work.

Monitor and evaluate

The need for using experience from the implementation stage in planning has already been enlightened. This suggests the need for effective monitoring and evaluation of implemented components. Monitoring takes place throughout the life of the program, and intents to provide information about how the monitored component is performing. Evaluation takes place after the completion of the program and examines if the intended objectives were achieved. You should make sure that monitoring efforts are targeted, always think about what for you need the information you collect.

Minimum monitoring should include a general recording practice of the sludge collection and monitoring the performance of the treatment plant.

☞ *Sources of further information: [2] Strategic planning for municipal sanitation – a guide. [8] Practical tools to achieve effective Operation & Maintenance.*
Useful tools: 3.2.2 Monitoring.

3 ENGINEERING TOOLS

3.1 Fecal sludge management and health

3.1.1 Disease transmission through poor fecal sludge management

Poor sanitation favors the transmission of diseases. Diseases related to poor sanitation may be caused by viruses, bacteria, protozoa or parasitic worms (helminthes). For health engineering purposes, these diseases are classified following their main transmission pathways. The classification is resumed in Figure 10.

Environmental Classification of Excreted Infections and Control Measures (after Feachem et al. 1983 and Mara 1996)			
Category and epidemiological features	**Prominent examples of infection**	**Dominant transmission mechanisms (*in italics : partly related to poor FS management)***	**Major control measures *(in italics: part of improvement of FS management)***
I Non-bacterial (fecal-oral) Zero latency; low to moderate persistence; low infective dose; unable to multiply; no intermediate host	Rotavirus diarrhoea Infectious hepatitis Amoebiasis Giardiasis Cryptosporidiasis Enterobiasis Hymenolepiasis	Person to person contact ***(or persons handling excreta)*** Domestic contamination	Improved water supply ***Hygiene education*** Improved housing ***Improved excreta disposal***
II Bacterial (fecal-oral) Zero latency; medium to high infective dose; medium to high persistence; able to multiply; no intermediate host	Campylobacter infection Cholera Pathogenic *E.coli* infection Salmonellosis Shigellosis Typhoid	Person to person contact ***(or persons handling excreta)*** Domestic contamination Water contamination ***Excreta or wastewater-fertilized crops***	Improved water supply ***Hygiene education*** Improved housing Improved excreta disposal ***Treatment of excreta or wastewater prior to use or discharge***
III Soil-transmitted helminths Latent; high persistence; unable to multiply; low infective dose; no intermediate host	Ascariasis Hookworm infection Trichuriasis	Yard contamination ***Fields, soil contamination*** ***Excreta or wastewater-fertilized crops***	***Improved excreta disposal*** ***Treatment of excreta or wastewater prior to use or discharge***
IV Tapeworm infections Latent; persistent; unable to multiply; low infective dose; cow or pig as intermediate host	Taeniasis	Yard contamination ***Fields, soil contamination*** ***Fodder contamination***	***Improved excreta disposal*** ***Treatment of excreta or wastewater prior to use or discharge*** Cooking of meat and meat inspection
V Water-based helminths Latent; persistent; able to multiply; low infective dose; intermediate aquatic host	Clonorchiasis (liver fluke) Schistosomiasis	Water contamination Fish	***Improved excreta disposal*** ***Treatment of excreta or wastewater prior to use or discharge*** Cooking of fish Control of snails
VI Spread by excreta-related insect vectors	Infections in categories I-III transmitted by flies or cockroaches Bancroftian filariasis (transmitted by the *Culex pipiens* mosquito	***Insect breads in various fecally contaminated sites***	***Identification and elimination of potential breeding sites*** (Improved domestic and peri-domestic hygiene) Improved sullage disposal Use of mosquito netting

Figure 10: Environmental classification of excreted infections and control measures (after Feachem et al. 1983 and Mara 1996)

Fecal sludge contains all infective organism excreted with human feces. These organisms can survive outside the human body for a limited period. Pathogenic bacteria die off within a few weeks (low persistence), whereas the eggs of parasitic worms can survive up to three years in the environment (high persistence). Fresh fecal sludge from public toilets contains the highest quantity of infective organisms. However, sludge from septic tanks also contains bacteria from fresh excreta and a large number of viable worm eggs. Fecal sludge needs to be considered as a very dangerous matter and requires careful handling. Poor management of fecal sludge can contribute to transmission of pathogenic organisms in various ways:

a) Careless handling of fecal sludge

Fecal sludge is handled during the removal from the facility and during transport and treatment. The persons most likely to get in direct contact with fecal sludge are the workers active in fecal sludge management. They are at very high risk to get infected by organisms contained in fecal sludge. The usual way of transmission is the direct fecal-oral way, which means that organisms contained in the sludge are ingested.

b) Discharge of fecal sludge into the environment

Once removed from a sanitation facility, fecal sludge often is discharged into the environment. Sludge may be dumped into a dumping site, into surface waters, into drains, or on the streets. In this way, the pathogenic organisms are dispersed into the urban environment where humans can get in contact with the germs. Children playing with contaminated water are especially at risk. A number of parasitic worms (geo-helminthes) develop infective stades in humid soil and the larvae then penetrate the human skin. All persons walking barefoot in areas where human excreta or fecal sludge are spread are at risk to get infected.

c) Use of untreated fecal sludge in agriculture

Fecal sludge is a good organic fertilizer and soil conditioner and therefore frequently used in agriculture. If the sludge is not adequately treated, pathogenic organisms contained in the sludge are dispersed on the fields. Here they can infect the farmers working on the fields as they permanently enter in contact with the contaminated soil and usually do not use protection measures. Bacteria and worm eggs may also attach to the plants and infect consumers if the crops are eaten raw and are not thoroughly washed.

3.1.2 How to cut the transmission pathways

The health risks from poor management of fecal sludge can be reduced by cutting the pathways on which diseases are transmitted. The following measures can be useful, depending on which of the above-described problems prevail:

a) Careful handling of fecal sludge

Manual handling of sludge is potentially dangerous and should be eliminated where it is possible. Especially manual vault or pit emptying can be replaced by mechanical emptying with vacuum suction units. Even in locations where conventional large equipment cannot access, it is possible to use small vacuum pumps specially developed for this situation. Use of adequate protection measures by workers is absolutely necessary when it is impossible to exclude manual sludge handling.

Protection measures for handling of sludge include the use of protection clothes such as gloves and masks and a good hygiene (washing hands after work etc.). Most important is that workers be aware of the nature of the health risks to which they are exposed and that they know how to protect themselves. Training of staff and targeted information may therefore be the most successful measures. Companies and municipal enterprises dealing with sludge should introduce rules for use of protection by their staff and care should be taken to enforce those rules.

b) Eliminate discharge of fecal sludge into the environment

Elimination of indiscriminate dumping of sludge is the most important measure to avoid that people get in contact with the pathogens contained in fecal sludge. It is important to collect as much as possible of the sludge removed from vaults and pits and to dispose it on sites designed for this purpose. It is absolutely necessary to make sure that nobody can access the disposal sites and that contamination cannot spread from these sites. Generally the latter requires that sludge has sufficiently reduced moisture content to exclude percolation in the underground and that disposal sites be constructed as sanitary landfills.

c) Treat fecal sludge before use in agriculture

Fecal sludge should always be treated prior to its use in agriculture. Treatment has then to provide sufficient pathogen reduction in the sludge to guarantee the safety of its use. The most resistant organisms in treatment are eggs of parasitic worms, in particular those of *Ascaris lumbricoides*. These eggs can only be destroyed by exposure to temperatures above 60°C, by desiccation at moisture contents lower than 10%, or by awaiting the natural die off after at least ½ year. Pathogen destruction by heat or desiccation can usually only be obtained with a considerable technological input, which is seldom affordable for fecal sludge treatment in developing countries.

The only “low-tech” treatment that can provide satisfactory pathogen destruction in a short time is termophilic composting. If composting is well done (the substrate has the right composition, moisture content and aeration are optimized) the temperature in the heaps usually rises above 55°C for several days and all pathogens are destroyed.

Storage of sludge over a period long enough to allow natural pathogen die off (minimum 6 months) is the other possibility to disinfect sludge without using expensive technologies. Natural drying hardly can provide a moisture content sufficiently low for complete pathogen destruction. Nevertheless, drying of sludge can enhance the pathogen destruction during storage and therefore increase the security of this method.

d) Use untreated sludge only for non-food crops

Agricultural reuse of fecal sludge for non-food crops can be possible without prior disinfecting treatment. In this way the health risks for consumers can be excluded. However, the farmers handling the fecal sludge are still at risk. The risk to farmer has then to be minimized through protection measures (a) or through hygienic education (e).

e) Hygienic education

Good personal hygiene breaks the direct contact routes by which pathogens are transmitted and the full impact of the measures described in a) to d) will only be achieved if they are accompanied by efforts to improve hygiene. Hygienic education should be targeted on all aspects of hygiene and sanitation, and not only on issues related to fecal sludge management.

3.2 Data collection

3.2.1 Sludge sampling and analysis

Why analyzing sludge?

Information about sludge characteristics is essential for design of treatment facilities. Fecal sludge is in general much more concentrated than municipal wastewater (10-100 times higher contents of organic pollutants and suspended solids). Its characteristics are very variable within one city because they depend on many factors such as the type of sanitation facility from which the sludge is removed, the intervals of emptying, the technique of emptying, etc. For this reason you cannot rely on literature data only for design parameters such as pollutant concentrations and sludge production per capita. In your specific situation these parameters may be quite different from other recorded cases.

Estimation of fecal sludge production

Knowing the sludge volumes produced in a certain area is necessary to design collection and treatment capacity. When estimating the volumes of sludge production, you should be very careful to distinguish between two notions of “sludge production”:

a) Sludge accumulation in vaults and pits [liters sludge per capita and year]

The more familiar notion is the sludge accumulation in pit latrines, septic tanks and other facilities, expressed in L/cap.yr. Standard values for this parameter appear commonly in wastewater and sanitation literature, where they are usually meant for design of on-site sanitation facilities (storage capacity for accumulating sludge). Using these values for the prediction of sludge volumes that need be handled and treated would, however, not be correct in most situations. It only would be admissible in the most ideal situation where all sludge produced by the population actually reaches a treatment plant. This would require that all on-site facilities be properly designed, be emptied in the designed intervals, and that all sludge be collected and disposed in the treatment plant. This scenario is very unlikely and it is therefore highly recommended to use the second notion of sludge production as described in point b).

b) Sludge collection rate [m^3 sludge collected per suction unit and year, or total volume arriving on a disposal point per year]

To obtain a realistic estimation of the amount of sludge to collect and treat, you have to take into account various aspects: Sanitation facilities may be improperly designed and not accumulate the expected quantity of the produced sludge. Not all sanitation facilities that accumulate sludge are actually emptied in regular intervals, or are emptied at all. Not all sludge in vaults or pits is removed during the emptying as often part of the solidified sediment remains in the facility. Not all sludge that is removed by companies or persons will be delivered to the treatment facility; part of the sludge will be dumped elsewhere. The sludge may be diluted during removal, volume and concentration be changed.

Hence, a realistic approach would be to base your estimations on the actual collection rates. If you use records of the current sludge collection (or produce those records), you will have at hand an estimation of the actual collection rate, which includes all the factors mentioned above. You will then have consider which points of the sludge collection you will seek to improve and you will have to try to quantify the repercussion of the improvements on the volumes of sludge likely to be collected. Estimation made in this

Nam Dinh – Estimation of fecal sludge volumes

The only de-slugging service likely to deliver sludge to a future treatment plant is the municipal enterprise URENCO. URENCO operates two vacuum tankers (capacity 4 m^3), which are used for de-sludging of septic tanks.

The average size of a septic tank is estimated to be 2.5 m^3. This figure has been estimated from an existent report of a household survey in Nam Dinh. It is considered that the average volume evacuated from a septic tank is the full content of 2.5 m^3, which includes both sediment and liquid supernatant.

URENCO indicated that under normal conditions, one vacuum tanker could empty two septic tanks per day. Currently only 100 to 150 tanks are emptied yearly. However, it is planned to increase operational capacity, to promote de-sludging service and to use the full capacity of the existent equipment.

The expected volume of fecal sludge volume is then estimated being 2500 m^3/year and the collection capacity can cover 1000 septic tanks or households per year (2.5 m^3 sludge per septic tank, 2 septic tanks per day and unit of equipment, 2 existing units, 250 operation days per year)

way will be much more realistic than the ones based on literature values, even if they still may contain a considerable uncertainty.

Sampling

Because of the variability of fecal sludge, you should try to take as many samples as possible. If resources for sludge analyzing are limited, you may rather reduce the number of analyzed parameters and take more samples instead. The minimum number of samples necessary to obtain representative results is around 50 samples. Less than 30 samples can generally only indicate tendencies but not give statistically significant data.

The best way of sampling is directly from the vacuum tankers. When discharging the tanker, you should collect sludge in a large bucket at the beginning of the discharging, when the tank is half empty and short before the end of discharging. Mix the sludge in the bucket thoroughly and take the sample from it. This way of sampling makes sure that you analyze sludge in the composition that actually would reach the treatment plant.

Direct sampling from sanitation facilities or from existing discharge tanks or ponds is not recommended. Suspended solids easily settle down when fecal sludge is stagnant. It is then impossible to obtain a representative sample without mixing up the whole content of the facility. Only sampling from the vacuum tanker takes into account that sludge may be diluted with water during emptying of vaults and pits.

Analyzing

You should carefully consider what for actually you need the information when choosing the parameters to analyze in sludge samples. Don’t bind resources for analyses that are not absolutely necessary.

Design of primary sludge treatment (solid-liquid separation) facilities is usually based on the solids content of the sludge, measured as suspended solids [SS] or total solids [TS]. The degree of stabilization of sludge indicates whether digestion of sludge is necessary and is measured by the BOD/COD ratio or by the content of total volatile solids [TVS].

Recommended parameters for fecal sludge analyzing			
Parameter	Typical concentrations in fecal sludge		Analyzing method * Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 19th edition 1995
	Low-strength (septage)	High-strength (public toilets)	
Minimum parameters (very simple and cheap to analyze, sufficient for first characterization of sludge)			
TS [%] (total solids)	0.5-3	<3.5	Drying at 105°C during 2 h *
TVS [% of TS] (total volatile solids)	<60	>60	Ignition at 550°C during 2 *
Complementary parameters (simple to analyze, complementary to TS and TVS)			
total COD [mg O_2/L]	6,000-15,000	20,000-50,000	COD, unfiltered sample *
Settling characteristics,[mL/L]	<300	Settling disturbed by gas-production	Settling test in 1 or 2 L cylinder, note settled volume after 2h
Other useful parameters (analysis requires reliable lab, useful for detailed design of treatment facilities)			
SS [mg/L] (suspended solids)	5,000-15,000	>30,000	Filtration of sample, drying of filter residue at 105°C during 2 h *
dissolved BOD_5, [mg O_2/L]	<500	>500	BOD_5 after filtration *
dissolved COD [mg O_2/L]	<1,000	>1,000	COD after filtration *
BOD/COD ratio	5:1…10:1	2:1…5:1	
NH_4-N [mg/L] (ammonia nitrogen)	<1,000	2,000-5,000	*

Figure 11: Important sludge parameters and recommended analysis.

Design of treatment of the liquid effluent from primary sludge treatment is based on the habitual parameters for wastewater treatment, in particular BOD, COD, SS and NH_4-N.

The parameters of fecal coliforms (for pathogenic bacteria) and viable helminthes eggs (for parasitic worms) generally indicate the content of pathogen organisms. You don't need to analyze these parameters as you can assume with certainty that fecal sludge contains dangerous concentrations of pathogens.

It is recommended to choose parameters that can be determined by simple laboratory methods. It is likely that you will have to rely on low standard laboratories where it may be difficult to produce reliable data for delicate parameters. Choosing parameters easy to measure will increase the reliability of your data. In the same time it helps reducing cost and enables you to analyze a higher number of samples, equally important for a reliable data basis. You may therefore prefer to analyze total solids rather than suspended solids, avoiding filtration that may be difficult with sludge samples. You may also prefer the simple analysis of volatile solids instead of the more difficult analysis of BOD and COD.

Especially BOD analysis with unfiltered sludge samples is not recommended, because the high solids content in the samples can cause erratic results.

3.2.2 Monitoring

General recording

Monitoring of implemented components should not only include technical aspects such as fecal sludge collection and treatment, but also organizational, institutional and financial matters. The most efficient way to do this is a good recording practice. Records about the work done and about the finances should systematically kept and archived in a way that allows easy access for those wanting to use the information. This is less obvious as it may seem. Very often the recording practice and even more the archiving practice is very poor and records are seldom really used for analyzing the quality of work. The most important point may be that the persons doing the work and responsible for recording are conscious that records will be needed and be used later. Some training of staff regarding recording and archiving may be necessary.

Fecal sludge collection

The workers themselves best do monitoring of sludge collection by recording the collection tours. Important points to record may be:

- Location (address) and type of the emptied facility
- Fee charged for the emptying
- Volume of sludge removed from the facility
- Date of emptying and date of last emptying

This data, if systematically recorded, is very valuable and can be used to establish a database about on-site facilities and their characteristics.

Fecal sludge treatment

A monitoring program for the treatment plant should be installed to supervise its functioning and to provide design information for extension phases. Regular analysis of the influents and effluents of the treatment should be done, for example on a weekly basis. An important monitoring parameter is the solids content (TS) of the sludge throughout the different treatment steps. Additionally you should verify if the treatment objectives are achieved and analyze the corresponding indicator parameters (for example BOD and COD in the liquid effluent and CF or helminth eggs in the in the dried sludge).

Records of operation of the treatment plant should also be kept in the way described for the fecal sludge collection. Entering fecal sludge volumes and leaving dry sludge volumes have to be recorded, as well as particular observations or problems during the treatment process.

Recording has to be done by the staff operating the treatment plant, whereas monitoring could also be done by an external contractor.

3.3 Technological options

3.3.1 Technologies for vault or pit emptying and sludge haulage

Large vacuum tankers, truck or cart mounted

The classical technology for emptying of toilet vaults or pits is by suction with a vacuum pump. A hose is introduced in the vault through a small opening and the content is sucked out. Sometimes stirring of the vault content and addition of water prior to suction may be required for loosening of the sediment layer. Sludge removal by suction pump largely minimizes the direct contact of the workers with the sludge and is therefore the safest technique available.

The pump is usually connected to a truck-mounted tank of variable capacity (1 to 10 m^3). In this way the truck can access the plot, empty the facility and then directly transport the sludge to the disposal or treatment site. This type of equipment is the same that is used in industrialized countries and is rather expensive (50,000 - 80,000 USD/unit). In developing countries the tanks are often mounted on carts pulled by tractor or animals. This version is considerably cheaper and technically equivalent to truck mounted systems. The disadvantage is the reduced mobility and action radiant due to the slower speed.

Mini vacuum tugs

Dwellings in urban centers of developing countries are often located in very narrow lanes that are inaccessible to large vehicles. Large suction units as described above are useless in this kind of situation and a large part of the households can therefore not be serviced with modern equipment. For this reason smaller units have been developed in various places, e.g. by UNCHS-Habitat in Nairobi, by WASTE in Dar Es Salaam or by Urenco in Hai Phong. This equipment consists of smaller tanks (200-500 L) and a motor or hand-driven vacuum pump. It can be hand-pushed or motor-driven. These units are not appropriate to transport sludge over longer distances. They need therefore be combined with truck mounted tankers or with intermediate storage and transportation tanks transported by hook-lift trucks.

The ideal solution in many cases would be to combine large equipment for the normal situations with smaller units for the areas difficult to access.

Manual emptying

Manual vault emptying will still be the final option when the use of vacuum pumps is excluded for certain reasons. Manual emptying can be acceptable if two points are respected: The health risk to workers must be minimized (see 3.1.2) and the transport to the disposal site must be organized. Both are much more organizational than technical problems. Good hygiene and protection clothes can reduce the health risks. Sludge can be transported by carts or in buckets to the disposal site. However it might be especially difficult to make independent workers bringing all the sludge to the desired site. Usually they earn their money from the fees emptying of vaults and not for transportation of sludge. Therefore they tend to dispose the sludge close to the emptying site in drains, fields or on the street. The only way to achieve that workers bring the sludge to designed site may be to provide appropriate incentive systems. Incentive systems should include both rewards for taking the desired actions and sanctions against harmful actions.

Figure 12: Truck mounted sludge tank (7,5 m^3) and vacuum pump in Hai Phong, Vietnam.

Figure 13: Mini-vacuum tug (350 L) for narrow lanes, used together with a intermediate-storage-tank placed in the next accessible road, Hai Phong, Vietnam.

Figure 14: Small sludge tank connected to a hand-driven vacuum pump in Mapet, Congo.

3.3.2 Technologies for fecal sludge treatment

Advanced treatment technologies are not described here

Treatment of fecal sludge in industrialized countries is usually based on technologies habitual for treatment of sewage and sewage sludge. Frequently used technologies include extended aeration, anaerobic digestion, mechanically stirred sludge thickeners, centrifuges, belt presses, vacuum filter presses, heat drying, pasteurization and others. However, all the mentioned technologies are not considered being adapted to most conditions in developing countries, because they are very expensive and have high operation and maintenance requirements. These “high-tech” options are therefore not described in this chapter.

Knowledge about simple treatment technologies is limited

A word of caution is needed before going into the details of available “low-tech” options for fecal sludge treatment. Knowledge about this type of treatment technologies is very limited. The research efforts for technologies adapted to conditions in developing countries always has been focussed on wastewater treatment exclusively. SANDEC has scientifically followed various fecal sludge treatment plants in several countries in order to contribute to close this knowledge gap and to develop design guidelines. The description of treatment technologies and the recommended design parameter given in this chapter are based on SANDEC’s research activities. Be aware that many of these recommendations are based on experiences from a single treatment plant and that you still have to use your own common sense when designing facilities. So far there isn’t existing a design manual for fecal sludge treatment that is used in practice.

Principles of fecal sludge treatment

Fecal sludge has several characteristics that make it difficult to handle. Fecal sludge cannot be discharged into surface waters or be treated like wastewater because its pollutant concentrations are too high. It cannot be landfilled or treated like solid waste because its moisture content is too high. It cannot be directly used for crop fertilizing because its pathogen content is too high.

The first stage of fecal sludge treatment thus mostly involves the stabilization of the sludge and the separation of the solid phase and the liquid phase. In this way the liquid part can be treated specifically, usually with wastewater treatment technologies. The solid part can further be treated to enhance its characteristics for either landfilling or agricultural reuse. Hence, sludge treatment involves different treatment steps where available techniques can be combined in various ways depending on the existing constraints and the treatment objectives.

Figure 15: gives an overview on the described treatment processes and some possible combinations.

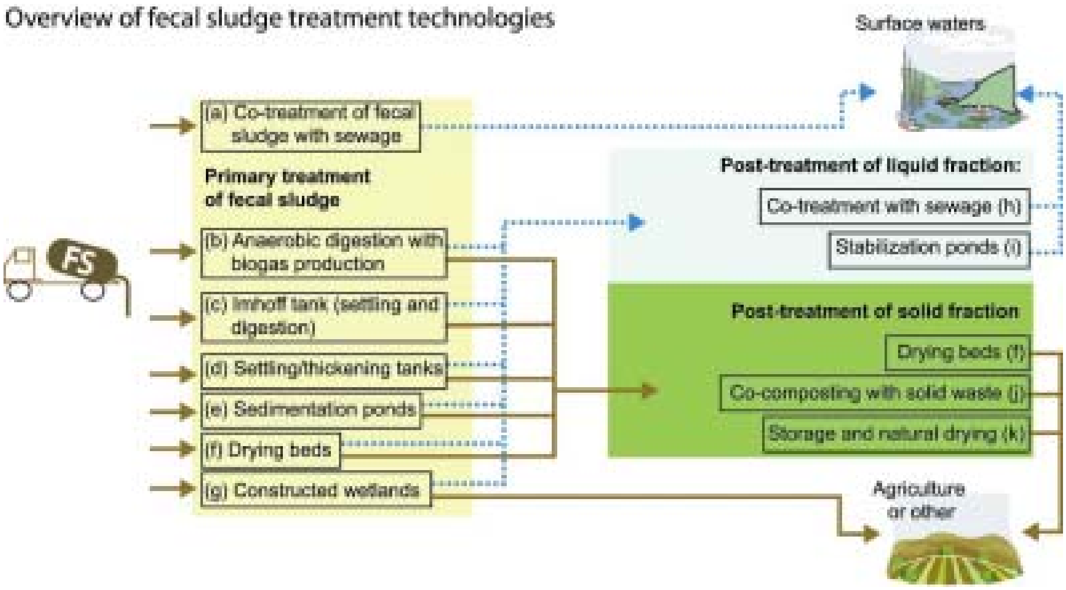
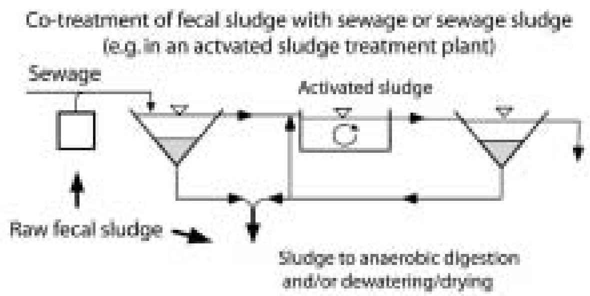


Figure 15: Overview of "simple" fecal sludge treatment technologies and their possible combinations

Receiving tank

Fecal sludge arriving at the treatment plant will usually first be discharged into a receiving tank. This tank should be equipped with a grid for removing the coarse objects. Additionally the receiving tans can function as buffering tank, receiving the sludge in a strong flush and passing then in a lower continuous flow on the primary treatment facility. All primary treatments expect ponds hardly tolerate loading in a strong flush.

a) Co-treatment of raw fecal sludge with sewage or sewage sludge



If a sewage treatment plant is existing or planned, FS can be co-treated with sewage. FS is mixed with sewage before treatment, or is mixed with sewage sludge before sludge treatment (if the STP is an activated sludge plant).

When to use? Condition is the existence or the project of a sewage treatment plant. The STP needs to have sufficient capacity to receive the additional load from FS.

Advantages: FS, when diluted with sewage, can be treated with well-known and reliable sewage treatment technologies. Co-treatment of FS and sewage may be economic.

Disadvantages: FS is mixed with chemically more contaminated sewage or sewage sludge. Agricultural reuse might be impossible and the resource FS be wasted.

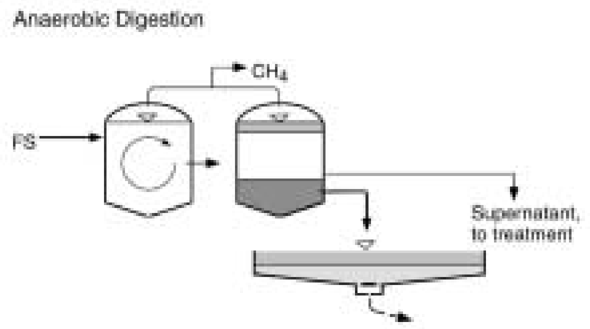
Design: It is necessary to verify if the STP has sufficient capacity to treat the additional pollution load from FS. The most critical parameter is usually suspended solids (SS). Other design parameters are COD, BOD_5, NH_4-N.

Primary treatment of fecal sludge

Primary treatment, in this context, designates further stabilization of the fecal sludge and the separation of solid and liquid phases. The quality of solids and liquids after primary treatment depends on the process. Post-treatment of solids and/or liquids may be necessary to achieve treatment objectives.

b) Digester for biogas production

Fresh FS rich in biodegradable organic matter is digested anaerobically, alone or together with animal dung or vegetal waste. The methane produced during the digestion is captured and can be used for cooking, lightening electricity generation. Liquid effluent and accumulated sludge leaving the digestion process are then treated separately.



When to use? Digestion of FS for biogas production can be interesting when there is a potential for use of the biogas. Only fresh FS (like from public toilets) is appropriate for biogas production. FS collected from septic tanks, pit latrines, etc. cannot be used for biogas production. The sludge needs to have a minimum solids content of 3%. Mixing with animal dung or with vegetal waste may increase solids content and content of digestible organic matter.

Advantages: Production of combustible and generation of revenues. Stabilization of fresh sludge. Little land requirements.

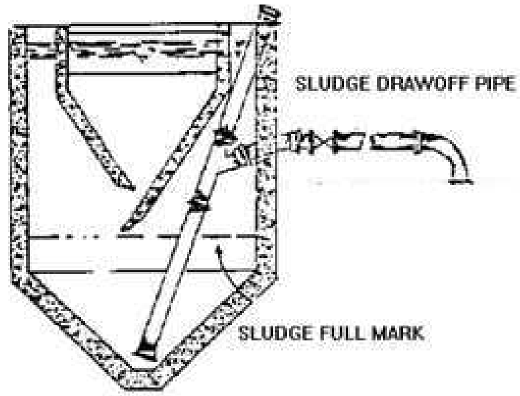
Disadvantages: The primary function of a biogas reactor is biogas production rather than sludge treatment. The biogas reactor is therefore generally an additional treatment process. Settling in digesters is incomplete and effluents require more extensive treatment efforts than effluents from other primary FS treatment processes. The structure is rather expensive, and operation requirements are quite considerable. Removal of settled and thickened solids can cause difficulties.

Design: Design is aimed at biogas production, reactor volumes usually are smaller compared to digesters for sewage sludge. Many different types of biogas reactors have been developed throughout the world. An example is the digester with floating gas dome as it is widely used in India for FS digestion. Following design values are frequently used: solids content (TS) in influent: 5–8 %; hydraulic retention time: 30 – 50 d, organic loading: 1.6-2.2 kg volatile solids (VS) /m^3.d.

c) Imhoff tank (settling and digestion)

The Imhoff tank allows settling of solids in presence of digestion processes. Inclined walls make sure that rising gas bubbles produced by anaerobic digestion do not disturb the settling process. Solids will accumulate on the bottom, be stabilized by digestion and thicken. The digested sludge will be removed periodically by pumping or hydrostatic pressure and further be treated. The clarified supernatant generally requires further treatment.

When to use? The Imhoff tank can be used for insufficiently stabilized FS to allow settling and digestion in one single stage. It can be used when conditions are not favorable for biogas digesters and when no space for stabilization ponds is available.

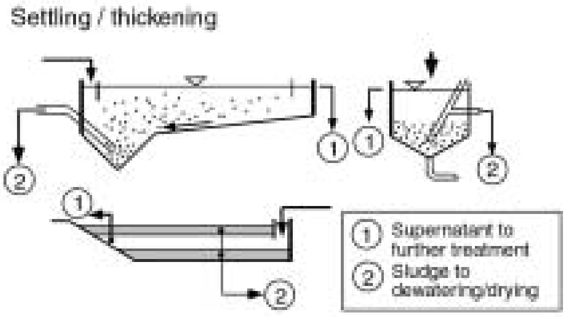


Advantages: Settling and digestion in a single step. Little land requirement.

Disadvantages: Expensive structure. Risk of obstruction of sludge draw-off pipe by thickened sludge when draw-off is not done in adequate frequency.

Design: The Imhoff tank has been developed for pre-treatment of wastewater in small treatment systems. Larger storage volumes for sludge and shorter sludge removal intervals have to be considered when adapting the design to FS treatment. The volume foreseen for settling (above the inclined walls) can be kept similar to the design for wastewater. Recommended design values: overall depth 2-3m; sludge accumulation depth 0.5–1 m; hydraulic retention time in settling compartment 4-8 h; sludge removal intervals 1-4 weeks, volume of accumulated sludge per incoming solids load 5-9 L/kg TS.

d) Settling/thickening tanks



In settling or thickening tanks, the solids accumulate at the bottom and the clarified supernatant can further be treated. The accumulated sludge is removed periodically through draw-off pipes. Another possibility of sludge removal is manually or by front-loaders after removal of the liquid column and a period of drying. Removed sludge generally requires further treatment.

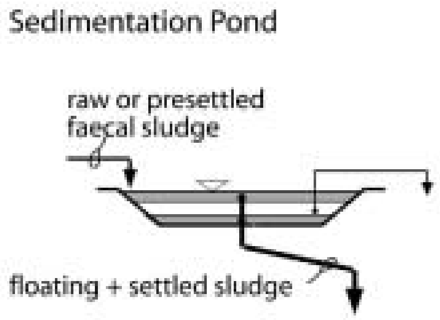
When to use? Settling tanks can be used for partly stabilized FS such as sludge from septic tanks and most other sanitation facilities. Settlings tanks are not appropriate for very fresh sludge from public toilets, but may still be suitable if the fresh sludge is diluted with more stabilized sludge.

Advantages: Simple and reliable process. Little land requirement.

Disadvantages: Not suitable for fresh FS.

Design: Settling tanks need sufficient volume for sludge accumulation and sufficient depth of the liquid column (> 1.5m) to allow good settling. The tanks should be equipped with baffle walls to maintain hydraulic conditions favorable to good settling and to retain floating scum. Design varies depending on the way of sediment removal. If sediment is removed by pumping or hydrostatic pressure, the tank should have a sludge hopper from where the sludge will be drawn off. If sediment is removed manually or by front-loaders the tank will be equipped with an access ramp. At least two parallel tanks will then be needed to assure continuos operation when one of the tanks is due for emptying. The tank size is estimated by choosing the sludge removal interval (2 weeks to 2 months) and with the assumed rate of accumulated sludge volume per incoming solids load of 5-9 L/kg TS.

e) Sedimentation/stabilization ponds



The sedimentation ponds use the same principle of sedimentation of solids as the settling tanks. Ponds are larger and have longer sediment removal intervals. Due to the high volume and long retention time, they provide a good stabilization capacity for fresher sludge. The sediment is removed after removal of the liquid column and a period of drying. Both liquid and sediments require further treatment.

When to use? Sedimentation/stabilization ponds can be used as first FS treatment stage when land availability is not a problem. They can receive fresh FS. Often they are the first stage in a sequence of stabilization ponds.

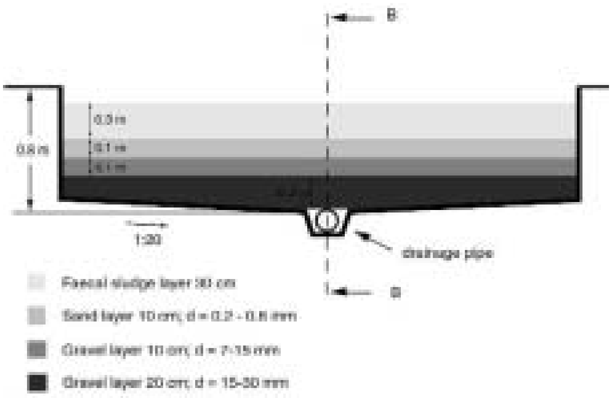
Advantages: Simple operation, cheap construction, better sedimentation properties as settling tanks, stabilization capacity.

Disadvantages: High land requirements.

Design: Sedimentation ponds are designed as anaerobic ponds with a sufficient storage volume for sludge accumulation. Sludge is removed once, twice or more often per year. At least two parallel ponds are required to assure continuos operation. The organic load of anaerobic ponds is 250-350 gBOD/m^3.d; the volume of accumulated sludge per incoming solids load is 0.8-2 L/kg TS.

f) Drying beds

Drying beds consist of a gravel-sand filter, equipped with a drainage system. Raw or pre-settled FS is loaded on the bed and the water is evacuated mainly by percolation through the filter and to a minor part by evaporation. The dewatered sludge is suitable for disposal. Further treatment for pathogen removal is necessary if the dried sludge is to be reused. Percolate quality improves through filtration but may still require a polishing treatment.



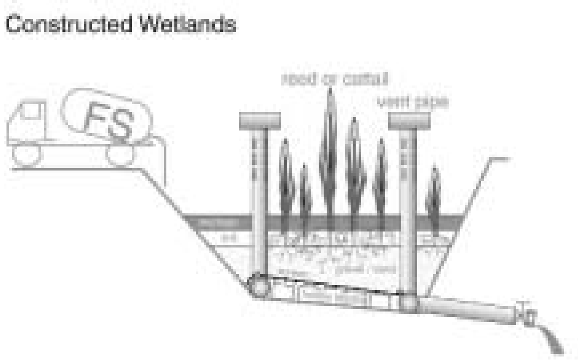
When to use? Drying beds can be used as first treatment stage and as second stage for dewatering of settled sludge removed from facilities such as described in b), c), d) and e). Drying beds cannot receive undiluted fresh FS (poor dewatering characteristics, odor emissions).

Advantages: Low moisture content of dried solids and relatively good percolate quality (compared to settling facilities). Technology is well known and reliable.

Disadvantages: Solids are not yet hygienically safe (unlike constructed wetlands)

Design: Various designs have been developed for drying of digested sewage sludge. The most frequently used type is the sand drying bed (see drawing above). They can be designed for a loading rate of 150-200 kg total solids (TS) per m^2 and year. Dried sludge can be removed after 7 to 14 days, depending on climatic conditions.

g) Constructed wetlands



A vertical-flow constructed wetland is a bed equipped with a drained gravel and sand filter and planted with marsh plants. The sludge is loaded on the bed and dewatered by percolation in the filter and by evapotranspiration through the plants. The root system of the plants maintains the permeability of the sludge layer and sludge can be added continuously. Sludge has to be removed only once every few years. The long solids retention period favors further mineralization and pathogen die-off and allows direct reuse of solids in agriculture. Percolate quality considerably improves but may still require a polishing treatment.

<u>When to use?</u> Constructed wetlands can be used when the sludge is to be reused in agriculture.

<u>Advantages</u>: Include dewatering, stabilization and hygienization in a single treatment stage, unlike all other treatment techniques. Dewatered sludge can be used in agriculture without further treatment. Percolate quality compares favorable to other primary treatments.

<u>Disadvantages</u>: Experiences from pilot plants only are available so far. Requires care for plant growth.

<u>Design</u>: The filter and drainage system of constructed wetlands is similar to a drying bed. The plants should be local marshland species that are tolerant to a wide range of environmental conditions (varying humidity, salinity). A freeboard for sludge accumulation of up to 1 m should be provided. Optimal performance has been observed for the loading rate of 250 kg total solids (TS) per m^2 and year. The sludge accumulation is then approximately 20 cm per year.

Post treatment of liquids

Post treatment of liquid effluents from primary treatment assures that the final effluent can be discharge into surface waters with no harm for the environment and public health.

h) Co-treatment of liquids with sewage

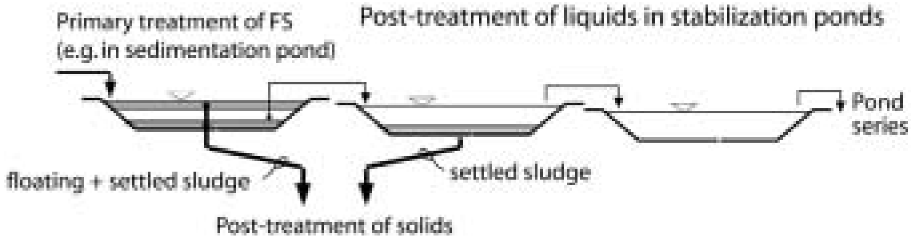
Effluents from primary FS treatment can be treated together with sewage if a sewage treatment plant is existing or planned. The primary treatment mainly eliminates the suspended solids and the STP can then treat much higher volumes of liquid effluent than of raw FS (compare to option a).

<u>When to use?</u> This option can be considered when there is existing or planned a sewage treatment plant, and when its capacity is not sufficient to treat raw FS.

<u>Advantages</u>: Co-treatment can save resources. The solids fraction is separated during the primary treatment and can be reused in agriculture (unlike option a).

Design: It is necessary to verify if the STP has sufficient capacity to treat the additional pollution load from pre-treated FS. Generally the greatest part of suspended solids will be removed in primary treatment. Removal of organic pollutants is minor during primary treatment, best in constructed wetland and rather poor in settling facilites. The critical parameters will therefore be BOD_5 and COD, further important are remaining SS and NH_4-N.

i) Stabilization ponds



Stabilization ponds for FS effluent treatment can be anaerobic or/and facultative ponds depending on the organic pollutant concentration. The first anaerobic pond after the primary treatment will still receive some suspended solids that will accumulate on its bottom. After occasional removal, the sediments can be treated together with the solids that have been separated in primary treatment

When to use?

Ponds can be used when sufficient land is available. High ammonia concentrations in the effluent, for example in FS from public toilets, may inhibit growth for algae and bacteria and thus the functioning of ponds.

Advantages: Simple, well-known and reliable technology.

Disadvantages: High land requirements. Possible inhibition of functioning through NH_3/NH_4 in case of very fresh FS.

Design: Stabilization ponds are designed for organic loading rates. Anaerobic ponds have 2-3 m depth, remove 60-70 % of BOD and produce no bad odors when loaded with 250–350 gDBO/m^3.d. Facultative ponds are 1-2 m deep and loaded with 350 kgDBO/ha.d.

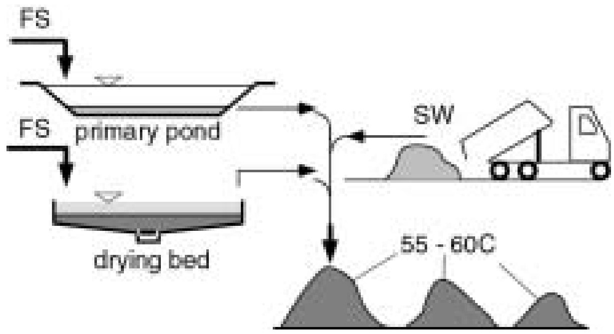
Post treatment of solids

Post treatment of solids assures the necessary quality corresponding to the treatment goals. If the solids are to be reused for food crop production, the treatment of solids has to provide hygienic safety of the solids. If solids will be used for non-food crops, be disposed off, or used for other purposes, the treatment basically has to provide adequate consistency of the solids.

j) Co-composting with solid waste

Pre-treated Fs (with reduced moisture content) is composted together with organic solid waste. If the composting is well done, temperatures in the heaps reach 55-60°C and all pathogens are destroyed. The produced compost constitutes a very good soil conditioner.

When to use?



Composting is a very interesting option when agricultural reuse of fecal sludge and solid waste is desired. Solid waste needs to be available in sufficient quantity and quality (sorting).

Advantages: Allows producing a good and pathogen free soil conditioner in relatively short time. Co-treatment can safe resources.

Disadvantages: Contaminants in solid waste may reduce compost quality.

Design: It is important that the mixture of SW and FS are optimal for composting. A moisture content of 50-60% and a C:N ratio of 30-35 should be guaranteed. Good aeration by frequent turning of the heaps is required to maintain thermophilic conditions. The composting process is generally completed after 6 weeks to 2 months.

k) Storage and natural drying

Storage over at least 6 months allows natural pathogen die-off in dewaterd sludge from settling facilities or drying beds. Further drying of sludge contributes to pathogen die-off and increases the safety of the method.

When to use? Storage and natural drying will be used if the fecal sludge is to be reused in agriculture and if co-composting or constructed wetlands (other processes delivering hygienically safe biosolids) are not favored.

Advantages: Cheap and simple.

Disadvantages: High land requirements.

Design: Protection against rain may be required depending on the climatic conditions.

4 SOURCES OF FURTHER INFORMATION

Case study of fecal sludge management planning

[1] Nam Dinh Septage management study

Florian Klingel; Nam Dinh Urban Development Project; SANDEC; November 2001

Download: http://www.sandec.ch/sos/references.html

This manual is based to a large extend on the practical experiences of the Nam Dinh Septage management study. The study aims to propose a feasible concept on how to improve the collection of fecal sludge and how to introduce adequate sludge treatment. The first part describes the thorough assessment of the situation, the problem analysis and definition of objectives. The main part deals with the development of the future management concept, including a discussion of technical and institutional ways to improve septage collection and an in-depth evaluation of various septage treatment technologies.

Sanitation planning

[2] Strategic planning for municipal sanitation – a guide

GHK Research and Training Ltd.; First edition; July 2000

Download: http://www.ghkint.com/pub_pub2.htm

The strategic planning approach of the present manual has largely been adopted from this guide. This guide contains the characteristics of a strategic approach for sanitation planning and step-by-step guides for policy development, for sanitation planning on municipal level and on local level. The last section of the guide contains a collection of tools for health and sanitation promotion, on sanitation technologies and sewage treatment, for sanitation choice, for information gathering, analyzing and sharing, for planning and management tools, and training modules

Community assessment

[3] Social Survey Methods - A fieldguide for development workers

Paul Nichols; Oxfam; ISBN 0-85598-126-1; 1991

Order: http://www.oxfam.org

A readable guide to selecting an appropriate, affordable research method, implementing the research, and communicating the results. Formal and non-formal survey methods are detailed, and advice provided on statistical analysis of results, design of survey forms and interview methods. This valuable tool is designed for those without formal training in statistics.

[4] Resources on Participatory Approaches and Communication for Water and Sanitation Programming: annotated references

Dick de Jong, Veera Mendonca and Silvia Luciani; IRC; 1997

Available: http://www.irc.nl/themes/communication/comres/index.html

This resource package on participatory approaches and communication tools aims to serve planners, implementers and field workers who are dealing with advocacy, social mobilization and program communication for change in water and environmental sanitation programming. This document incorporates a variety of annotated information: important publications, training manuals, workshops, training courses and other resources available.

[5] Metguide – Methodology for participatory assessment with communities, institutions and policy makers. Linking sustainability with demand, gender and poverty.

Rekha Dayal, Christine van Wijk, Nilanjana Mukherjee; WSP; 2000

Download: http://www.wsp.org/pdfs/global_metguideall.pdf

The metguide mainstreams gender and poverty indicators into a participatory methodology that can be used to monitor key aspects of sustainability. It provides a means for stakeholders at various levels – community, project and service provider, and policy – to clearly visualize how actions can contribute to the goal of sustainability. It uses quantitative statistical methods to analyze qualitative data obtained from communities through participatory techniques.

Technologies

[6] Fecal sludge treatment

Agnes Montangero, Martin Strauss; Lecture notes IHE Delft; February 2002

Download: http://www.sandec.ch/sos/references.html

These lecture notes summarize SANDEC's to date research results in fecal sludge treatment. Current practices and problems in fecal sludge management, strategic and regulatory aspects are addressed at first. The main part is about fecal sludge treatment, including descriptions of various treatment options and investigated facilities in different countries. The paper concludes with chapters about option evaluation and about land requirements.

[7] Solids separation and pond systems for the treatment of fecal sludges in the tropics - lessons learnt and recommendations for preliminary design

Udo Heinss, Seth A. Larmie, Martin Strauss; SANDEC Report No. 5/98

Download: http://www.sandec.ch/sos/references.html

The report sets out to provide guidelines for the preliminary design of fecal sludge treatment schemes comprising solids-liquid separation and stabilization ponds. The document is based on the results of field research conducted on full and pilot-scale fecal sludge treatment plants located in Accra, Ghana. The authors first inform on fecal sludge quantities and characteristics. Effluent and solids quality standards for fecal sludge treatment plants are discussed and a set of guideline values proposed. The document then proceeds to discuss results of field research conducted on FS pretreatment; i.e., solids-liquid separation in sedimentation/thickening tanks, dewatering/drying beds and anaerobic pond technology and the results of field investigations conducted with anaerobic ponds.

[8] Practical tools to achieve effective Operation & Maintenance

WHO; Operation and Maintenance Working Group; 2001

Download: http://www.who.int/water_sanitation_health/wss/o_m.html, WHO CH-1211 Geneva 27, Switzerland

The Working Group Operation and Maintenance has developed a series of tools which can be used at the country level to improve O&M performance. The tools have been developed in response to the demand for practical solutions to the sector's problems. They include guidelines, manuals, training packages, and case studies.

Those currently available are:

- *Tools for Assessing the Operation and Maintenance Status of Water Supply and Sanitation in Developing Countries.* These comprehensive guidelines show how to assess O&M performance in both rural and urban areas.

- *Operation and Maintenance of Urban Water Supply and Sanitation Systems: A Guide for Managers.* This publication examines the factors, which may prevent existing urban water supply systems working efficiently, and provides guidelines and solutions for optimization.

- *Operation and Maintenance of Rural Water Supply and Sanitation Systems.* This package contains resource material for training courses aimed at improving the management of O&M in rural areas.

- *Models of Management Systems for the Operation and Maintenance of Rural Water Supply and Sanitation Systems.* This document evaluates the factors which influence the development of O&M management systems for rural facilities. It describes models in eight representative countries and offers guidance to planners and designers in selecting the most appropriate one.

- *Linking Technology Choice with Operation and Maintenance.* This document helps users to make more appropriate technology choices by providing information on the O&M implications - particularly the costs - of selecting a specific technology.

Hygiene promotion

[9] Just stir gently – The way to mix hygiene education with water supply and sanitation

IRC; Technical Paper Series No. 29; ISBN 90-6687-016-8; 1991

Order: http://www.irc.nl/products/publications/index.html or IRC, P.O. Box 93190, 2509 AD The Hague, Netherlands

Provides options and methods for integrating hygiene education with water supply and sanitation projects. Illustrations and examples are used to reinforce the text and to give some ideas from 'real life' situations. Target audience is those responsible for the development and implementation of hygiene education components in water supply and sanitation projects.