Chapter 1

The Global Situation

Linda Strande

1.1 INTRODUCTION

Solutions for effective and sustainable faecal sludge management (FSM) presents a significant global need. FSM is a relatively new field, however, it is currently rapidly developing and gaining acknowledgement. This chapter provides an introduction to what FSM is, some of the unique challenges of FSM, an overview of the systems level approach for implementation and operation presented in this book, and additional resources that are available on the internet.

1.2 WHAT IS FAECAL SLUDGE?

Faecal sludge (FS) comes from onsite sanitation technologies, and has not been transported through a sewer. It is raw or partially digested, a slurry or semisolid, and results from the collection, storage or treatment of combinations of excreta and blackwater, with or without greywater. Examples of onsite technologies include pit latrines, unsewered public ablution blocks, septic tanks, aqua privies, and dry toilets. FSM includes the storage, collection, transport, treatment and safe enduse or disposal of FS. FS is highly variable in consistency, quantity, and concentration.

1.3 GLOBAL RELEVANCE

The sanitation needs of 2.7 billion people worldwide are served by onsite sanitation technologies, and that number is expected to grow to 5 billion by 2030 (Figure 1.1). It is a common perception that onsite technologies fulfil sanitation needs for rural areas, but in reality, around one billion onsite facilities worldwide are in urban areas. In many cities, onsite technologies have much wider coverage than sewer systems. For example, in Sub-Saharan Africa, 65-100% of sanitation access in urban areas is provided through onsite technologies (Strauss *et al.*, 2000). However, despite the fact that sanitation needs are met through onsite technologies for a vast number of people in urban areas of low- and middle-income countries, there is typically no management system in place for the resulting accumulation of FS. It is evident that the management of FS is a critical need that must be addressed, and that it will continue to play an essential role in the management of global sanitation into the future.

In the past, sludge management from onsite facilities has not been a priority of engineers or municipalities, and has traditionally received little to no attention. Several generations of engineers have considered waterborne, sewer-based systems as the most viable, long-term solution to fulfil sanitation needs. Onsite technologies have traditionally been viewed as only temporary solutions until sewers could be built. This practice is a result of the effectiveness of sewer-based approaches throughout Europe and North America in cities where water is for the most part readily available, as

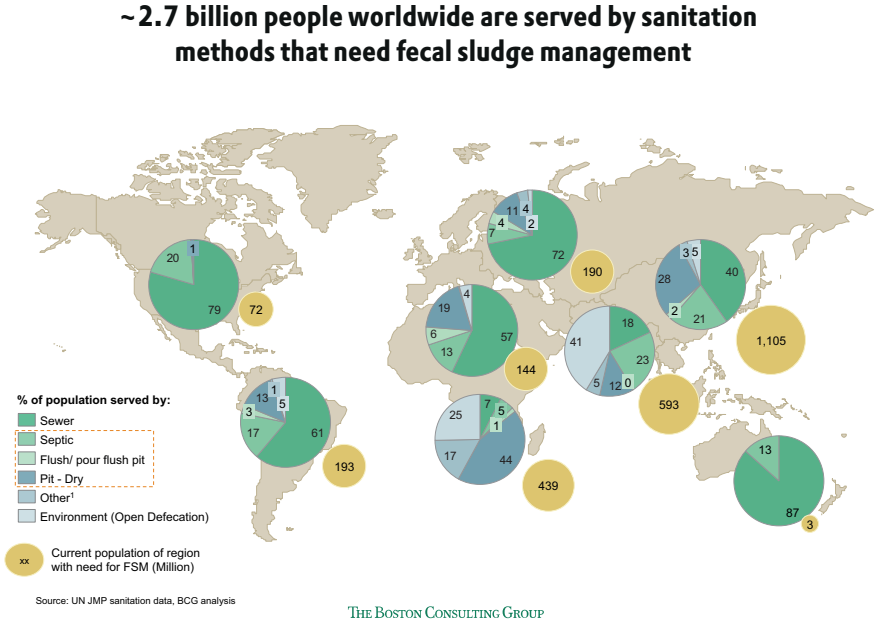


Figure 1.1 Percent of population served by onsite sanitation technologies (Reproduced with permission from the Boston Consulting Group; 2013).

well as out-of-date engineering curricula, and the preference for large-scale infrastructure investments by development banks and governments. However, the expansion and development of functioning, conventional sewer networks is not likely to keep pace with the rapid urban expansion typical of low- and middle-income countries. In addition, where sewers and wastewater treatment plants (WWTPs) have been constructed in low-income countries they have most frequently resulted in failures. Over the last 15 years, the thinking of engineers worldwide has started to shift, and people are starting to consider onsite or decentralised technologies as not only long-term viable options, but possibly the more sustainable alternative in many ways compared to sewer-based systems which are prohibitively expensive and resource intensive. In urban areas, it has been demonstrated that, depending on local conditions, the cost of FSM technologies are five times less expensive than conventional sewer-based solutions (Dodane *et al.*, 2012).

Increasing access to sanitation is a global priority. Currently one in five children die from diarrheal-related diseases, which is more than that of aids, malaria, and measles combined (UNICEF and WHO 2009). In addition to health benefits, improved sanitation has significant economic benefits, for example the return on one USD spent on water and sanitation improvements in low-income countries is 5-46 USD depending on the intervention (Hutton *et al.*, 2007). Progress towards the Millennium Development Goals (MDGs) has been successful in increasing access to *improved*[1] sanitation facilities. However, providing adequate access to sanitation facilities does not end when onsite technologies are built. The promotion of onsite technologies has greatly reduced open defecation, but without solutions

1 Target 7C - reducing by half the number of people without access to 'improved' sanitation. Improved is defined as systems that hygienically separate human excreta from human contact, and includes: flush toilets, connection to a piped sewer system, connection to a septic system, flush/pour-flush to a pit latrine, ventilated improved pit (VIP) latrines, and composting toilets.

or funding to maintain their functionality through appropriate FSM, it has also resulted in numerous cases in a sludge management crisis, having significant impacts on human and environmental health. Onsite technologies can represent viable and more affordable options, but only if the entire service chain, including collection, transport, treatment and safe enduse or disposal, is managed adequately. Without an FSM structure in place, when the containment structure fills up, the untreated FS most likely ends up directly in the local environment (Figure 1.2). This results in the pervasive contamination of the environment by pathogens and is not providing a protective barrier to human contact and hence protection of public health. For example, in Dakar only 25% of FS that accumulates in onsite facilities is being collected and transported to legitimate FSTPs (BMGF, 2011). When developing sanitation goals and implementing sanitation projects, it is imperative to consider *downstream sanitation*, beyond only a focus at the household level and only providing toilets.

Effective management of FS systems entails transactions and interactions among a variety of people and organisations from the public, private and civil society at every step in the service chain, from the household level user, to collection and transport companies, operators of treatment plants, and the final enduser of treated sludge. Sewer systems and FSM can be complementary, and frequently do exist side-by-side in low-income countries. A very successful example of this management model is in Japan where the systems successfully co-exist in urban areas (Gaulke, 2006).

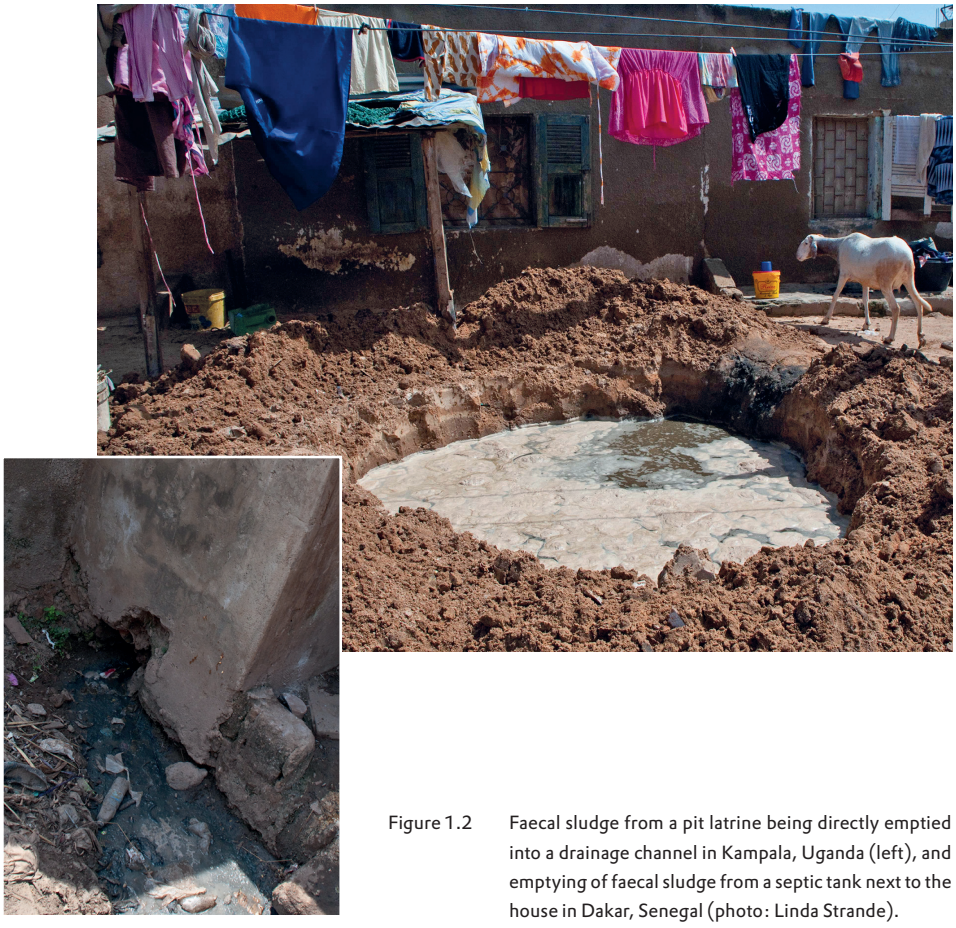


Figure 1.2 Faecal sludge from a pit latrine being directly emptied into a drainage channel in Kampala, Uganda (left), and emptying of faecal sludge from a septic tank next to the house in Dakar, Senegal (photo: Linda Strande).

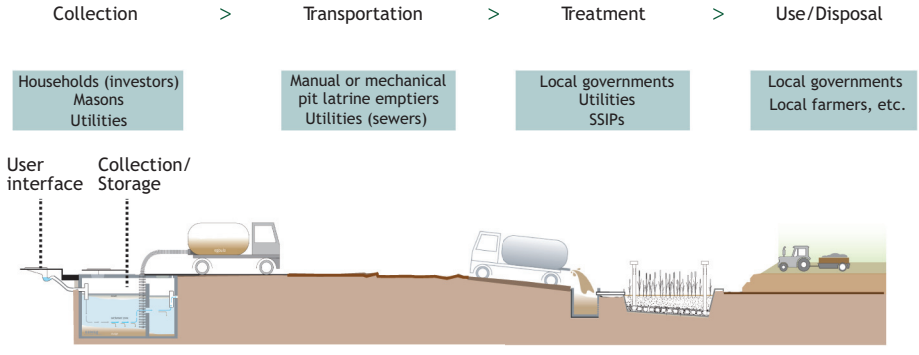


Figure 1.3 Sanitation and faecal sludge management service chain (Parkinson *et al.*, 2013).

The complete sanitation service chain is shown in Figure 1.3, the FSM component is specifically the emptying, collection, transport, treatment and enduse or disposal of FS. Factors such as technology designs and options for user interfaces, or onsite collection and storage methods to reduce sludge volumes are covered in more detail in The Compendium of Sanitation Systems and Technologies, which is also available free of charge from the SANDEC website (Tilley *et al.*, 2014). Weak links in the FSM service chain include many factors, such as household level users not being able to afford professional emptying services; collection and transport trucks not being able to access narrow lanes and paths leading to houses; operators not able to afford the transport of FS over large distances to treatment facilities; and the lack of legitimate FS discharge locations or treatment facilities. The solution to overcoming these problems and designing functioning and sustainable FSM requires a systems-level approach that addresses every step in the service chain. To move towards complete and functioning FSM service chains, this book develops an integrated systems-level approach that incorporates technology, management and planning.

1.4 BOOK OBJECTIVE

Developing solutions for FSM is a serious global problem that has received limited attention over the past twenty years (Strauss and Heinss, 1996). Compared to wastewater management practice, there is a hundred year gap in knowledge of FSM in urban areas. However, the FSM field is now rapidly developing and gaining acknowledgement, as shown by many recent examples where municipalities are adopting FSM into their urban planning (e.g. Dakar, Senegal and Ouagadougou, Burkina Faso), and the commitment of organisations like the Bill & Melinda Gates Foundation placing significant resources into research of FSM. Recently, experience through pilot and full-scale systems has started becoming available (Figure 1.4), but practice is still not up to desired speeds. As awareness of the need for FSM has increased, so has the need for solutions. However, information on FSM is generally not readily available and therefore the objective of this book is to present an approach for the comprehensive and integrated management of FS in urban and peri-urban areas of low- and middle-income countries. This book aims to contribute to filling the knowledge gap by bringing together and presenting the current state of knowledge in the field.

The target audience of this book includes students and practitioners in the field who are or will be designing, planning, promoting, or managing FSM systems. The book provides a comprehensive approach that includes an overview, design guidelines of treatment technologies, important considerations of operations and maintenance for successful operation of implemented technologies, and a planning approach so that all necessary requirements are met to ensure a long-term, sustainable system. The book assumes the reader has basic knowledge of sanitation and wastewater treatment.

The book is expected to contribute to readers' better understanding of treatment, management and planning aspects of FSM; enable them to identify suitable treatment options; understand the mechanisms and designs of specific treatment technologies; and enable them to communicate important aspects of FSM to stakeholders involved in the process including managers and decision makers. The book is also relevant for employees of municipalities, national sanitation utilities, consultants, donor agencies, decision makers, and waste-related businesses in order to expand their knowledge, understanding and overview of integrated FSM systems.

The book was designed as a learning tool with many elements of a textbook. Each chapter includes learning objectives so it is clear what readers can gain from the chapter. The end of chapter study questions help to evaluate whether the learning objectives are achieved. Where relevant, example problems are also included to illustrate how any calculations were made, and case studies are included to describe the importance of real-life lessons learned in each of the covered areas. As such, the book can also be used in any classroom setting, and is currently used in the context of a newly developed three week course on FSM as well as in a new online course on FSM offered within the program of UNESCO-IHE Institute for Water Education.

Figure 1.4 Class 2014-2016 of the Master Specialisation in Sanitary Engineering at UNESCO-IHE (photo: UNESCO-IHE).

1.5 DESIGNING FOR FAECAL SLUDGE MANAGEMENT TREATMENT ENDUSE

When designing treatment technologies, the final enduse or disposal option of sludge and liquid streams should first be determined, so that obtaining the appropriate level of treatment for the desired enduse can be incorporated into the design. Once the final enduse or disposal options have been selected, it becomes possible to work backwards starting from the final treatment requirements to design a system that achieves the treatment objectives. For example, pathogen reduction and level of sludge dryness requirements will be very different if the intended endproduct is compost for use on food crops or if it is fuel for use as combustion in industrial processes. These decisions are context specific, and need to be made based on local regulations and the market demand for endproducts. Similar to designations for Class A and Class B biosolids in the United States, FS is treated for levels of pathogen reduction that make it appropriate for different enduses. This approach is important to ensure that effluents and endproducts achieve adequate and appropriate levels of treatment; systems are not over-designed, wasting financial resources; and that systems are not under-designed risking public and environmental health.

Resource recovery from treatment products should be considered as a treatment goal whenever possible, but the number one goal is obviously the protection of public health. In many low- and middle-income countries, regulations for the enduse of sludge do not exist and/or are not enforced. In the apparent lack of a regulatory environment, the required levels of treatment becomes a societal decision. On the other hand, standards that are too strict may also have a negative impact if they prevent action from being taken because they cannot be met. To ensure adequate protection of human health, a multi-barrier approach is recommended, as described in Chapter 10, Enduse of Treatment Products. Financial flows from the sale of endproducts can also help to achieve the sustainability of treatment options, as they offset sludge disposal costs, potentially provide a revenue stream, help to ensure treatment plants are operated well to provide quality products, and provide a benefit to society through resource recovery. This type of context-specific solution needs to take into account the local market demand, and ways to increase the value of treatment products as markets vary significantly among locations (Diener *et al.*, 2014).

1.5.1 Systems approach

For sustainable implementation and ongoing operation, FSM requires an integrated systems approach incorporating technology, management and planning, as depicted in Figure 1.5. In this book, chapters fall under each of the technology, management or planning sections, as is clearly presented throughout the book by the colour scheme, but what is of utmost importance is how all three of these fields come together to provide a framework that will guide practitioners from the initial project planning phase to implementation and ongoing operations and maintenance phases. A multi-disciplinary, systems-level approach to FSM like that developed here is required to ensure that untreated FS is removed from the community, not remaining at the household level, and that it is treated in a safe and effective manner. For example, removing sludge from the household is a private interest, but the FSM service chain is a public interest, requiring regulation and enforcement by an authority that is responsible for the public good. If only a few people in a community properly manage FS, it would not have a net impact on the community as a whole; there needs to be collective participation at the community scale to ensure that public health benefits are realised. This requires sustained public sector commitment, effective policies, appropriate implementation and enforcement to promote understanding and adherence (Klingel *et al.*, 2002), topics that are covered in the Planning and Management sections.

Although technologies are an integral and essential component of FSM, they should not be considered in isolation. Planning and management methodologies presented in this book will help form the fundamental foundation that long-term successful FSM systems are built on. They not only represent the first phase of designing a system, but are necessary to ensure a continuum of success throughout the

life of a project. As presented in the planning section, ideally all key stakeholders will realise the need for and have desire to participate in the planning stages, including public authorities, entrepreneurial collection, transport, and treatment service providers, and the serviced and impacted communities. Methods for increasing stakeholder engagement will help to ensure that stakeholders have a long-term investment in the success of the system, and will continue to provide feedback that results in further improved solutions. This can be aided by clearly defining responsibilities, communication, and coordination mechanisms during the planning phases. Including an integrated planning approach helps to ensure vested participation and management, without which technologies implemented in low-income countries will fail over the long term.

In this book, the planning process includes exploring the situation (identify stakeholders and their interactions; understand the existing situation; develop goals and objectives); developing solutions (including institutional, financial, and technical aspects); and defining measures for implementation (Klingel *et al.*, 2002). This covers organisational, institutional, financial, legal and technical aspects of the entire FSM service chain, from the collection and transport, to the final disposal or enduse of treatment products, and is necessary to coordinate and ensure varied and complex levels of service, among stakeholders that have diverse interests. This FSM planning approach includes understanding and matching stakeholders' interests, needs and constraints with an appropriate institutional framework, financial mechanisms, capacity and the initial situation. This type of integrated planning can prevent previous failures, for example, locating a FS treatment plant on the outskirts of a city where land is available and relatively inexpensive, meaning that the costs associated with haulage time and distance for collection and transport companies is prohibitive, resulting in direct dumping of FS in the environment, and the treatment plant not being used.

Management factors presented in this book, such as institutionalisation, technical capacity, legal frameworks and cost recovery mechanisms, will help to ensure long-term success of FSM technologies (Bassan *et al.*, 2014). Management concerns need to be incorporated into technology decisions, for

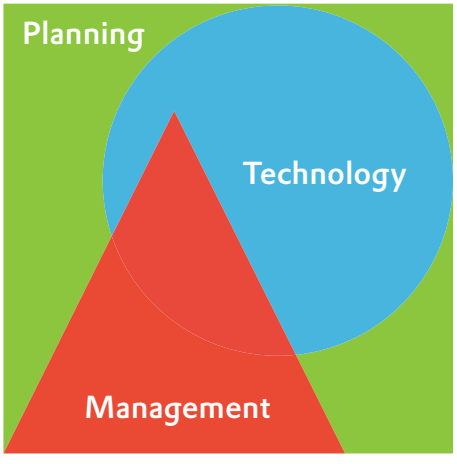


Figure 1.5 Faecal sludge management requires an integrated systems level approach, incorporating technology, management and planning.

example locally available or reparable pumps to ensure ongoing operation of technologies when pumps break down. Environmental regulations can be in place, but will require adequate enforcement for adherence. Evaluating and implementing financial structures that can sustain the system ensures financial viability and long-term operation, including appropriate financial incentives and sanctions (Wright, 1997). Methods to ensure running costs are covered so the entire system can operate in an affordable fashion need to be determined, as well as ways that financial transfers throughout the service chain can provide adequate funding for each step in the chain.

This systems-level approach includes evaluating in existing systems what can be done for improvement at each step in the chain, and then most importantly, how all the steps integrate and influence each other. For example, could resource recovery from treatment products be a financial driver for the service chain, ultimately reducing collection fees at the household level, and thereby increasing access to sanitation? Could a significant market demand for treatment endproducts such as use as an industrial fuel provide a financial incentive for collection and transport companies to deliver FS to treatment facilities instead of discharging it untreated directly into the environment?

This book contains 18 chapters, subdivided into the technology, management and planning sections, plus The Global Sitation and The Way Forward chapters. This approach covers individual topics in a focused matter, yet embeds and links them to each other throughout the book. Chapters 2 – 10 are focused on technical aspects of collection, transport and treatment, Chapters 11 – 13 are focused on examples of on-going management of FSM systems, and Chapters 14 – 17 are focused on planning integrated FSM systems. Each chapter presents different aspects of that field, and then how they can all be combined into one integrated approach is brought together in Chapter 17 Planning Integrated FSM Systems where a logical framework is presented that highlights the tasks and activities that need to be included in designing a comprehensive system.

Chapter 2 Quantification, Characterisation and Treatment Objectives

This chapter presents an overview of the challenges and objectives of FSM from the technology perspective. It covers the difficulties in obtaining reliable data for estimating the quality and quantity of FS that is produced in a city, introduces parameters that are important in FS characterisation and how they are analysed. Examples are provided to illustrate the wide range of high, medium and low strength FS that has been observed in the field, and explains some of the operational factors responsible for this variability. The chapter then explains what treatment targets and objectives are in an FSM system.

Chapter 3 Treatment Mechanisms

This chapter presents the basic scientific mechanisms that existing technologies rely on for the treatment of FS, to provide the reader with a more in-depth understanding of how technologies function, and their operation and maintenance requirements. It explains key parameters that need to be monitored and optimised to ensure treatment efficiency, and how to assess which treatment mechanisms are appropriate for a given context.

Chapter 4 Methods and Means for Collection and Transport

This chapter presents the current state of knowledge for how FS can be collected from onsite technologies, and transported to treatment facilities, including the role of transfer stations. Technologies are explained including social, procedural and technical aspects. Manual (Figure 1.6), manually operated mechanical and fully mechanised technologies are presented. The importance of health and safety issues regarding FS collection and transport are also presented.

Figure 1.6 Transport of faecal sludge in an informal settlement in Nairobi, Kenya (photo: Linda Strande).

Chapter 5 Overview of Treatment Technologies

This chapter presents an overview of potential treatment technologies. It presents well established technologies, which are then covered in more detail in respective chapters, technologies that appear to be very promising but have had limited implementations, and promising technologies that are still in the research phase. The advantages, constraints and field of application of each treatment option are presented, and information provided so the reader can compare and contrast the potential performance and scope of appropriate application. It also emphasises the importance of finding a context-adapted combination of technologies, and the parameters that are important to consider when designing a system.

Chapter 6 Settling-Thickening Tanks

This chapter provides information on the design and ongoing operations and maintenance of settling-thickening tanks. It presents information on when settling-thickening tanks are adequate treatment technologies, the fundamental mechanisms of how they function, and their potential advantages and disadvantages. Information is provided on how to design a settling-thickening tank according to the desired treatment goal.

Chapter 7 Unplanted Drying Beds

This chapter presents an overview of unplanted drying beds for sludge dewatering. It explains their main components and how they affect the performance of drying beds. It provides an understanding of the appropriate level of operations, maintenance and monitoring for their performance. Information is provided on how to design drying beds according to the desired treatment goal.

Chapter 8 Planted Drying Beds

This chapter presents an understanding of planted drying beds for sludge dewatering and stabilisation. It presents an overview of the vegetation types that can be used, and the role they play in sludge dewatering. Information is provided on the appropriate level of operations, maintenance and monitoring for their performance. Information is provided on how to design planted drying beds according to the desired treatment goal and context-specific parameters.

Chapter 9 Co-treatment with Wastewater

This chapter presents information on the co-treatment of FS with municipal wastewater. The possibilities discussed include activated sludge, anaerobic digestion, and anaerobic ponds. This chapter presents information on the extreme care that must be exercised when considering combined FS and wastewater treatment, as the system can be overloaded and fail even when relatively small volumes of FS are added to the wastewater treatment plant. Information is presented on the fractionation of organic matter and nitrogen compounds in FS. Key considerations and potential impacts of FS co-treatment in wastewater treatment systems are explained, and results of calculations of the volume/load of FS that can effectively be co-treated with wastewater are presented.

Chapter 10 Enduse of Treatment Products

This chapter presents information on the safe enduse or disposal of FS treatment products. The importance of resource recovery, combined with adequate protection of human and environmental health is stressed. Existing options for resource recovery are presented, along with innovative options that are still in the research stage of development. Information is presented on how to determine rates for the land application of sludge, and possibilities for the enduse or disposal of liquid streams.

Chapter 11 Operation, Maintenance and Monitoring

This chapter presents information on critical operations and maintenance factors that should be considered when building and operating a FSTP. It introduces operations and maintenance manuals, the importance of monitoring activities, and why and how administrative management is crucial to the long-term successful operation of an FSTP.

Chapter 12 Institutional Frameworks

This chapter presents information on the institutional framework that needs to be in place for an effective FSM-enabling environment. It presents regulations and contracts that can be used for enforcing adequate service. The main strength and weaknesses of stakeholders related to the institutional framework are explained, and an overview of the potential institutional arrangements for the distribution of responsibilities in the service chain is provided. Advantages and drawbacks of different institutional arrangements are also discussed.

Chapter 13 Financial Transfers and Responsibilities

This chapter presents information on possibilities for different models of financial flows among stakeholders in the FSM service chain. It explains what types of financial transfers play a role, necessary incentives, sustainable tariffs, and what legal and institutional frameworks have to be in place. It also explains the complexity and difficulty of designing, implementing, monitoring and optimising the financial flows for an entire FSM system.

Chapter 14 Assessment of the Initial Situation

This chapter presents the first step in the planning process, how to understand what is important to know at the beginning of the FSM planning process, and what information needs to be collected. It explains different methods and tools for collecting the relevant data, and how to identify shortcomings and challenges of the existing FSM systems and enabling environment.

Chapter 15 Stakeholder Analysis

This chapter presents why stakeholder analysis is important in FSM project design, and how to perform a stakeholder analysis including identifying and characterising the key stakeholders and relationships. It also explains how the stakeholder selection evolves throughout the planning process, and how to determine stakeholders that need empowerment, incentives, capacity-building or other forms of information.

Chapter 16 Stakeholder Engagement

This chapter presents why it is important to engage stakeholders from the very beginning of project implementation, and how this is effective in easing project implementation and to enhance long-term sustainability. It explains how to use information gathered during the stakeholder analysis to plan stakeholder involvement and how to distribute and formalise roles and responsibilities, and it provides tools to inform, consult and collaborate with stakeholders.

Chapter 17 Planning Integrated Systems

This chapter presents the importance of tying together all of the information presented in the book into one integrated planning approach. It links all the technology, management, and planning aspects developed in the book and explains how they are all connected and influence each other. A logical framework is presented that highlights the tasks and activities that need to be included in designing a comprehensive system. The chapter illustrates how to plan an integrated FSM system at the city level and how to select context-appropriate options.

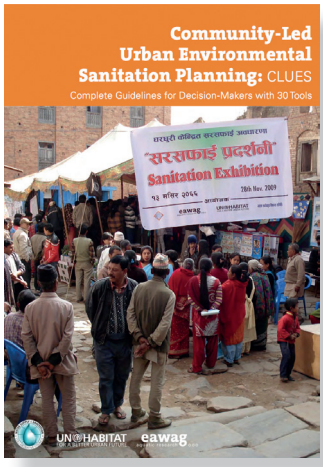
Chapter 18 The Way Forward

This chapter discusses lessons that have been learned, what is still lacking in the field of FSM, and how we can move forward in developing and obtaining the necessary knowledge.

Available Resources

In addition to this book, there are many resources available free of charge via the internet for designing and improving complete access to environmental sanitation. All of these tools should be used in conjunction with each other to ensure the most sustainable and comprehensive approach possible. Resources include:

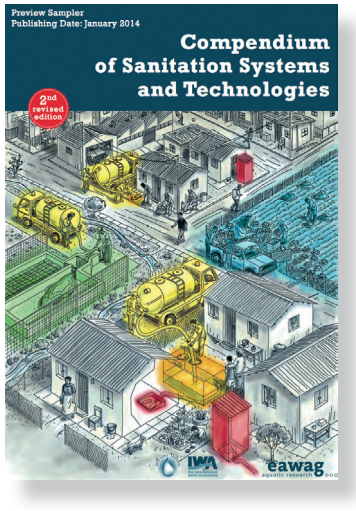
Community-Led Urban Environmental Sanitation (CLUES), EAWAG/WSSCC/UN-Habitat



CLUES presents a complete set of guidelines for sanitation planning in low-income urban areas. It is the most up-to-date planning framework for facilitating the delivery of environmental sanitation services for urban and peri-urban communities. CLUES features seven easy-to-follow steps, which are intended to be undertaken in sequential order. Step 5 of the planning approach relies on the Compendium, applying the systems approach to select the most appropriate technological option(s) for a given urban context. The document also provides guidance on how to foster an enabling environment for sanitation planning in urban settings.

Published in 2011, 100 pages, with a memory key. It is available for download at: www.sandec.ch/clues.

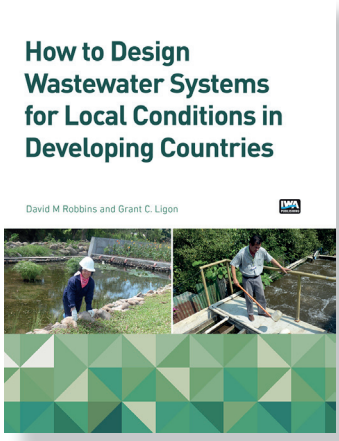
Compendium of Sanitation Systems and Technologies



The Compendium is a guidance document for engineers and planners in low- and middle-income countries, primarily intended to be used for communicative planning processes involving local communities. It is also intended for persons/experts who have detailed knowledge about conventional high-end technologies and require information, for instance, on infrastructure and different system configurations. It is not intended as a standalone document for engineers, making decisions for the community, e.g., expert-driven decision-making.

The Compendium of Sanitation Systems and Technologies was first published in 2008 during the International Year of Sanitation. This new version contains more technologies, a simplified user guide as well as a section on emerging technologies while keeping the same structure: brief, concise and connected. It will be available for download at: www.eawag.ch/sandec.

How to Design Wastewater Systems for Local Conditions in Developing Countries (RTI/IWA)



This manual provides guidance in the design of wastewater systems in low-income country settings. It promotes a context-specific approach to technology selection by guiding the user to select the most suitable technologies for their area. It provides tools and field guides for source characterisation and site evaluation, as well as technology identification and selection. This manual is primarily addressed to private and public sector service providers, regulators and engineers/development specialists in charge of implementing wastewater systems. RTI edited the manual, and IWA published it in 2014. It is available for download at: http://www.iwapublishing.com/template.cfm?name=isbn9781780404769_&type=new.

Expanding your knowledge in a course

Over the last few years, the knowledge and understanding of FSM has advanced extensively. For the new generation of scientists and engineers entering the sanitation profession, the quantity, complexity and diversity of these new developments can be overwhelming, particularly in low-income countries where access is not readily available to advanced level courses in FSM. This book seeks to address that deficiency. It assembles and integrates materials of experts around the world that have made significant contributions to the advances in FSM. The book also forms part of a three-week course at UNESCO-IHE Institute for Water Education as well as of an internet-based curriculum (online course) in FSM and, as such, may also be used together with lecture handouts, filmed lectures by the authors and tutorial exercises for readers' self-study. Upon completion of this curriculum, modern approaches to FSM can be embraced with deeper insight, advanced knowledge and greater confidence.

Figure 1.7 Graduating class of Masters of Science from UNESCO-IHE. In addition to being used in the Masters curricula, this book makes part of the distance-learning course on faecal sludge management and of the newly established Postgraduate Diploma Program in Sanitation and Sanitary Engineering at UNESCO-IHE (photo: UNESCO-IHE).

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