1

Setting the stage

Linda Strande
Konstantina Velkushanova
Damir Brdjanovic

OBJECTIVES

The objectives of this chapter are to:

- Introduce city-wide inclusive sanitation (CWIS)
- Define faecal sludge
- Explain the need for standard methods
- Provide an overview of the book chapters
- Present additional resources

1.1 CITY-WIDE INCLUSIVE SANITATION

City-wide inclusive sanitation (CWIS) is becoming the new paradigm in thinking about globally appropriate solutions for urban sanitation. The goal of CWIS is equitable, safe, and sustainable sanitation for everyone. Access to safely managed sanitation can be achieved through implementation of a range of appropriate technologies tailored to the realities of rapidly growing cities, with integrated combinations of sewered and non-sewered, and onsite, decentralised, and centralised technologies (Gambril *et al.,* 2020; Schrecongost *et al.,* 2020). Faecal sludge management (FSM) refers to the safe containment and treatment of non-sewered sanitation, and as illustrated in Figure 1.1, integrated faecal sludge management plays a vital role in CWIS.

Figure 1.1 An example of the role of integrated faecal sludge management in city-wide inclusive sanitation (CWIS), with networked solutions including sewer-based and non-sewer-based sanitation solutions. Colours illustrate the faecal sludge management service chain. Red: user interface; orange (underground): onsite containment; yellow: collection and transport; green: treatment; blue: end use as resource recovery (source: Eawag).

Centralised, sewer-based technologies are well established, with a long record of research, knowledge, and implementation (Jenkins and Wanner, 2014), and guidelines for onsite containment of excreta in rural areas are well accepted (Wagner and Lanoix, 1958). In comparison, the concept of integrated faecal sludge management in urban and peri-urban areas is relatively new. Some technology solutions exist at the level of 'established' (*e.g.* existing guidelines for implementation and operation), whereas others are at the level of 'transferring' (*e.g.* not yet established, being adapted from other applications), or 'innovative' (*e.g.* still in the development phase) (WHO, 2018). There is a need for greater scientific knowledge to move solutions for faecal sludge management forward, a need that this book is designed to address through methods of data collection, analysis, and interpretation.

The importance and need for faecal sludge management has been recognised worldwide, and with rapidly occurring developments, it is an exciting time in the sanitation sector. The incorporation of the entire faecal sludge management service chain in the Sustainable Development Goals (SDGs), launched in 2015, has further established acknowledgement of its importance. There has also been an increase in the incorporation of faecal sludge management in national regulations and development agency agendas, increased funding from foundations and governments, and implementation of infrastructure and service provision. Curricula in CWIS are being developed and implemented, there is an increase in evidence-based research and journal publications, and an emerging new generation of students, practitioners, and scientists, the future champions in developing and implementing sanitation solutions.

It is important that the professional sanitation community maintains the momentum of these positive developments, and continues to focus efforts on these drivers of change, as there is still much work ahead. Cities in low- and middle-income countries are rapidly growing, with only a fraction of faecal sludge safely managed. For example, based on shit-flow diagrams (SFDs) in 39 cities, over 50% of excreta in urban areas remains untreated, with discharge of faecal sludge into open drains, onsite containments that are not emptied and are overflowing, and dumping of faecal sludge directly into urban environments (Peal *et al.,* 2020). To achieve CWIS, there is a need for further development of more policies and institutional frameworks with clear responsibilities; integrated planning methodologies for drinking water, wastewater, grey water, rainwater, and solid waste (Narayan *et al.,* 2021); sustainable business models and revenue fee structures (Otoo and Drechsel, 2018); and increasing knowledge dissemination and

capacity development. There is a need for the development of improved and sustainable solutions for the future, while managing in parallel the existing faecal sludge crisis.

One of the goals of this book is that increased scientific knowledge will lead to an increased understanding of faecal sludge characteristics, its quantification, and correlation to source populations. Through increased scientific knowledge, and by remaining open and inquisitive, optimal new solutions can be developed. Based on this, research can lead to an understanding of treatment mechanisms in order to advance technologies from the level of innovative and transferring to established, and to reduce required footprints for treatment in urban areas (Gold *et al.,* 2016). Reliable data can improve projections and modelling, which are needed for the design of treatment plants and transfer stations (Englund *et al.,* 2020). Laboratory experience can lead to the development of methods that are lower cost and easier to implement, which could be used for the dynamic operation of faecal sludge treatment plants to adapt to highly variable loadings (Klinger *et al.,* 2019). Monitoring of treatment performance can lead to treatment plants designed for appropriate levels of treatment based on type of resource recovery (Andriessen *et al.,* 2019). Established methods for scaling up laboratory- and pilot-scale solutions can facilitate increased uptake and advancement of knowledge and experience. The closed-loop solutions being investigated with the Reinvent the Toilet Challenge (RTTC) can be based on onsite treatment technologies such as hydrothermal carbonisation, microwave technology, supercritical oxidation, pyrolysis, and electrochemical processes (Hiolski, 2019). Established methods of data collection and analysis can be used to establish guidelines and monitoring for the protection of public and environmental health, and advancements in scientific knowledge will elevate the perception of onsite sanitation as a sustainable component of CWIS.

1.2 WHAT IS FAECAL SLUDGE?

Faecal sludge management refers to the storage, collection, transport, treatment, and safe end use or disposal of faecal sludge (Strande *et al.,* 2014). Faecal sludge is defined very broadly as what accumulates in onsite sanitation technologies and specifically is not transported through a sewer. It is composed of excreta, but also anything else that goes into an onsite containment technology, such as flushwater, cleansing materials and menstrual hygiene products, grey water (*i.e.* bathing or kitchen water, including fats, oils and grease), and solid waste. Hence, faecal sludge is highly variable, with a very wide range of quantities (*i.e.* produced and accumulated volumes) and qualities (*i.e.* characteristics). In this book, faecal sludge is grouped by consistency as 'liquid' (TS <5%), 'slurry' (TS 5-15%), 'semi-solid' (TS 15-25%), and 'solid' (TS >25%).

To better understand what faecal sludge is, it is helpful to look at the different definitions for excreta, faecal sludge, and wastewater (or sewage), and their service chains, as shown in Figure 1.2.

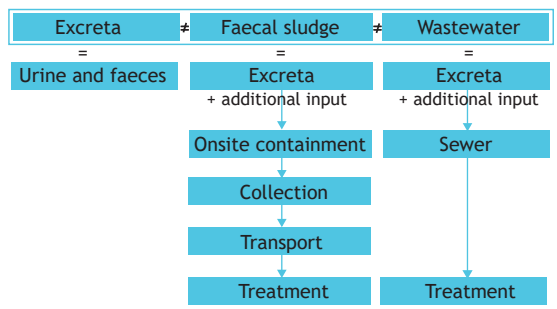

Figure 1.2 Comparison of excreta, and the sanitation service chain for management of faecal sludge and wastewater (source: Eawag).

Excreta is urine and faeces. Faecal sludge and wastewater are composed of excreta, together with additional inputs, and are both designed for the safe management of the resulting waste streams. The main difference between faecal sludge and wastewater is the respective sanitation service chains, which has very significant ramifications for management, cost, appropriate treatment, and quantities and qualities (Q&Q) (Dodane *et al.*, 2012). Faecal sludge is stored onsite, and is periodically collected and transported to a faecal sludge treatment plant, followed by safe disposal or end use. In contrast, wastewater also

contains excreta, but it is transported via a sewer and in general contains larger volumes of flush water, grey water, and rainwater, which conveys it to a wastewater treatment plant. Hence, the service chains of wastewater and faecal sludge are entirely different, with faecal sludge management relying on a complex service chain that depends on interactions between people at every step (Englund and Strande, 2019).

In addition to the service chain, Q&Q of faecal sludge and wastewater are very different, with the range of faecal sludge characteristics being 1-2 orders of magnitude higher than wastewater (Figure 1.3, A and B). Wastewater is mixed during transport in the sewer, meaning that what is delivered to treatment is relatively homogenised. In contrast, the heterogeneity of faecal sludge observed at the level of containment is directly transferred to the treatment plant (Figure 1.3, C). It is important to note that wastewater influent and faecal sludge delivered to treatment plants also follow different statistical distributions and deviations, and that faecal sludge typically does not follow a normal distribution, with standard deviations that can be as high as mean values (Figure 1.3, A and B). Hence, when reporting the results of data analysis, more comprehensive summary statistics should be used to convey the variability, such as average, standard deviation, median, and quartile values, and the sharing of complete raw data sets is strongly encouraged[1].

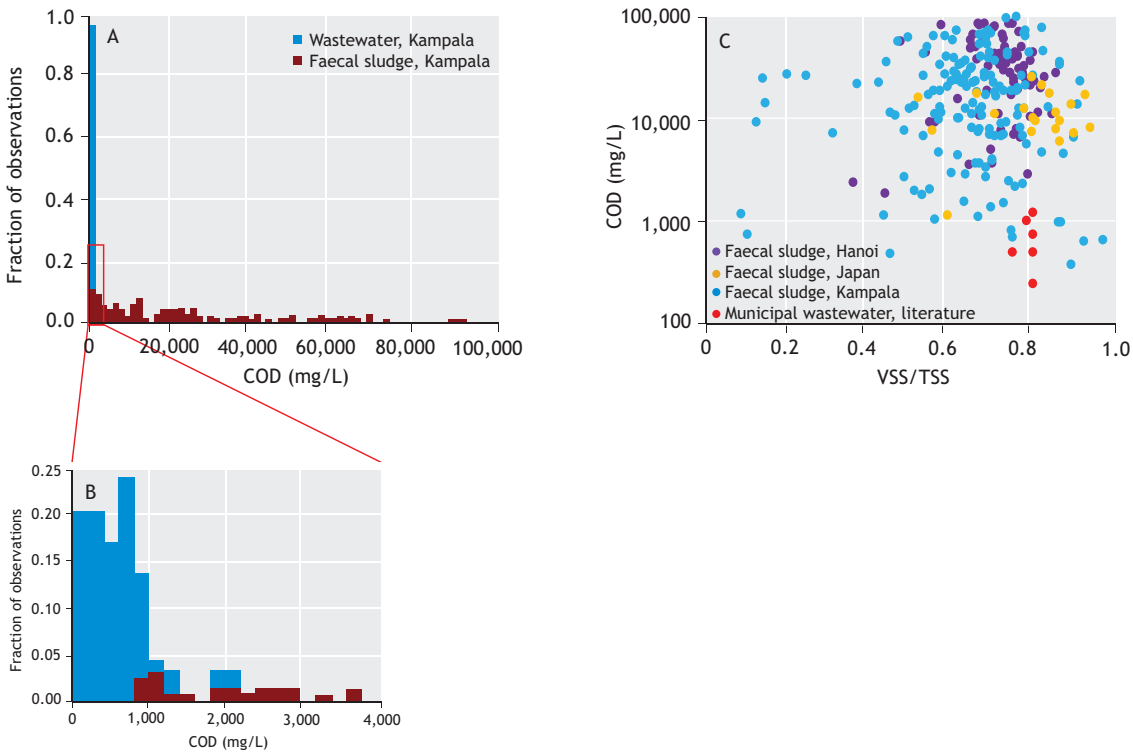

Figure 1.3 A) Histogram showing distribution of influent chemical oxygen demand (COD) values for the Lubigi wastewater and faecal sludge treatment plant in Kampala, Uganda. 32 wastewater and 143 faecal sludge samples, with an average COD for faecal sludge of 23,550 mg/L and standard deviation of 23,433. B) Enlargement of the X axis for comparison to wastewater (Englund and Strande, 2019). C) COD concentration and volatile suspended solids to total suspended solids (VSS/TSS) ratio for untreated faecal sludge collected at faecal sludge treatment plants or from collection trucks (Gold *et al.*, 2018; Englund *et al.*, 2020), and influent of untreated domestic wastewater (Tchobanoglous *et al.*, 2014; Henze *et al.*, 2008; Von Sperling *et al.*, 2020).

[1] For example: https://doi.org/10.25678/0000tt

Usage of the word 'sludge' varies and can be confusing, as there are several different types of sludge, and terminology is used differently by different practitioners. For example, types of wastewater sludges include sludge that settles out in the sewer, or sludges that are separated from liquid flows within wastewater treatment plants (Figure 1.4). In contrast, 'faecal sludge' is conventionally referred to as 'faecal sludge' throughout the service chain, from the time it accumulates in containments, and passes through collection, transport, and delivery to treatment facilities. The terminology of faecal sludge also varies depending on geographic location, professional background, or preference, but different terminology does not change the actual definition or characteristics. For this reason, as the sector continues to develop, agreed terminology for the faecal sludge management service chain will be an important development. In the meantime, during analysis and reporting of results, it is important to clearly describe where and how samples were taken to ensure transferability of results. Different types of sludge have widely varying characteristics and are not comparable, due to different storage conditions and treatment processes (*e.g.* redox conditions, level of stabilisation, biomass, nutrients, particle size, undigested plant fibres, salts and ions, and extracellular polymeric substances (Ward *et al.,* 2019). For example, faecal sludge from septic tanks is also commonly called 'septage', and might or might not include sludge, scum or supernatant layers. In addition, septic tanks commonly do not operate as designed, and/or what many people frequently refer to as 'septic tanks' are in reality more like cess pits. Hence, it is important to develop standard methods of sampling, analysis, and reporting of data, and to report exactly what is referred to when analysing and reporting Q&Q of 'faecal sludge'.

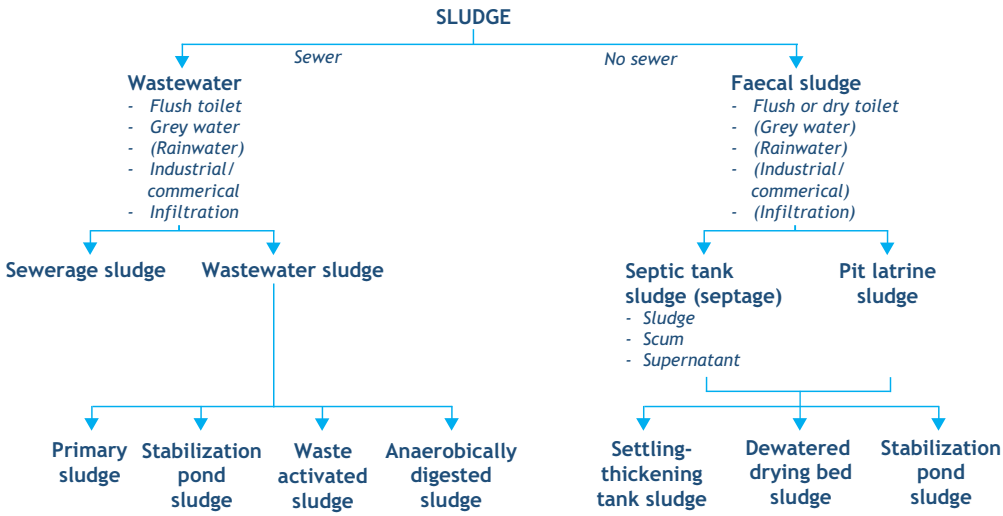

Figure 1.4 Examples of terminology used for types of sludge resulting from 'sewer-based' (wastewater) and 'non-sewer-based' (faecal sludge) sanitation components in an integrated approach to city-wide inclusive sanitation (Englund and Strande, 2019).

1.3 TOWARDS STANDARDISATION OF METHODS FOR FAECAL SLUDGE ANALYSIS

This book, *Methods for Faecal Sludge Analysis*, compiles methods of data collection, analysis, and interpretation specifically for faecal sludge, which until now have been lacking. In contrast, *Standard Methods for the Examination of Water and Wastewater* was first published in 1905, and *Methods of Soil Analysis* in 1965, both with multiple subsequent editions (Rice *et al.,* 2017; Klute, 1986; Page, 1983; Sparks *et al.,* 1996). Due to this lack of standard methods for faecal sludge, methods from water, wastewater, and soil and food science have been applied to faecal sludge. The problem is that they are not necessarily directly transferable to faecal sludge, which has very different characteristics. Methods for faecal sludge sampling are also greatly complicated by the wide range of technologies in each local context, and the heterogeneity within sanitation systems. Due to the lack of standard methods for sampling, laboratory approaches, analytical methods, and projections and modelling, the sector lacks a definitive source of respected guidelines to follow, which has translated into results that are not comparable. In addition, without established methods for data validation, results are not meaningful. This has greatly complicated the transfer of knowledge and data between different regions and institutions, and limited the ability to learn from each other and advance scientific understanding.

One of the goals of this book is to start developing 'standard' methods for faecal sludge analysis to improve communication among practitioners, designers, researchers, students, and teachers, to build comparative faecal sludge databases of information, and to increase confidence in obtained results. With this aim, the electronic version of this book has been made available free of charge for everyone. Although there are not yet 'standard' methods, this book addresses these challenges and provides a basis to start to establish them. The methods presented in this book have been peer-reviewed, and have wide acceptance in the sector. Now that this first round of methods has been compiled, they can start to undergo the required steps to become official 'standard' methods. This will require international, collaborative validation, where blind samples are independently analysed in parallel in different laboratories, and methods are further evaluated for precision and ruggedness (Rice *et al.,* 2017, method 1040). In moving towards standardisation, a committee of members of the Global Partnership of Laboratories for Faecal Sludge Analysis (GPLFSA)[2] is coordinating these processes. The GPLFSA was established in 2018 to address the need for increased communication between the growing number of laboratories equipped for faecal sludge analysis.

A further goal of this book is to be dynamic and keep pace with rapid developments. The list of methods presented in this book is meant as a starting place that will continue to grow and develop. As the need for new methods arises, existing methods will need to be adapted and new methods developed to fill the gaps. Tips for adapting existing methods for application to faecal sludge are included in Chapter 8, and guidelines for developing standard methods are covered in Rice *et al.* (2017), method 1040. As these changes are taking place, publications are needed that can adapt more quickly than the time required for new books and book editions to be published. The GPLFSA webpage provides a platform for exchanging information on method development that is regularly updated and publicly available, together with an ongoing conversation through a dedicated web application channel. The webpage includes video explanations and examples of methods, and online tutorials and courses. The GPLFSA will continue to disseminate this knowledge and experience through different platforms such as the IWA Specialist Groups, the SuSanA forum, the FSM Alliance, and the Global Sanitation Graduate School (GSGS). For information on how to stay updated, or become involved in the process, visit the GPLFSA webpage.

[2] https://sanitationeducation.org/laboratories/

1.4 INTEGRATED APPROACH TO DATA COLLECTION

This book provides an integrated approach to data collection and analysis of faecal sludge in order to generate meaningful data. As illustrated in Figure 1.5, the entire process must be coordinated, and aspects of each chapter are interrelated. The objectives of each of the book chapters are summarised in Table 1.1. The first step in using the book is to define the overall objectives that the methods can fulfil, and what information is required to achieve it. For example, this could be setting up a monitoring program at a treatment plant, defining a research question, or collecting data to design an integrated faecal sludge management plan. Further examples are provided throughout the book chapters. The next step is to make a plan for data collection to carry out the defined objectives. This will include a sampling plan (*e.g.* for monitoring), and could also include a research plan. Information on how to set up a sampling plan is covered in Chapter 3, examples of laboratory strategies for the upscaling of technologies from laboratory or pilot-scale are provided in Chapter 4, macro- and micro-scale projections of Q&Q of faecal sludge in chapters 5 and 6, and the use of simulants (recipes for synthetic faecal sludge) that can be used in research are the focus of Chapter 7.

An integral part of making a data collection strategy, is to determine which specific properties of faecal sludge need to be quantified to achieve the defined objective. Then, in an iterative process, while further refining the plan for data collection, the specific analytical methods that will be used to characterise the selected properties are selected based on the available resources and desired level of accuracy. Information on how properties of faecal sludge are influenced along the service chain are described in Chapter 2, and the analytical methods and procedures related to safe handling, storage, sample preparation, and disposal are provided in Chapter 8. The final steps are carrying out the developed sampling plan, conducting the laboratory analysis, and analysing and interpreting the obtained data. Guidelines of how to set up a faecal sludge laboratory are provided in Chapter 2, further examples of data collection are applications for scaling-up technologies in Chapter 4, and projections and modelling of Q&Q of faecal sludge in chapters 5 and 6.

With the completion of these steps, it is important to transparently share and disseminate the results widely, in order to advance the scientific knowledge of faecal sludge and management solutions.

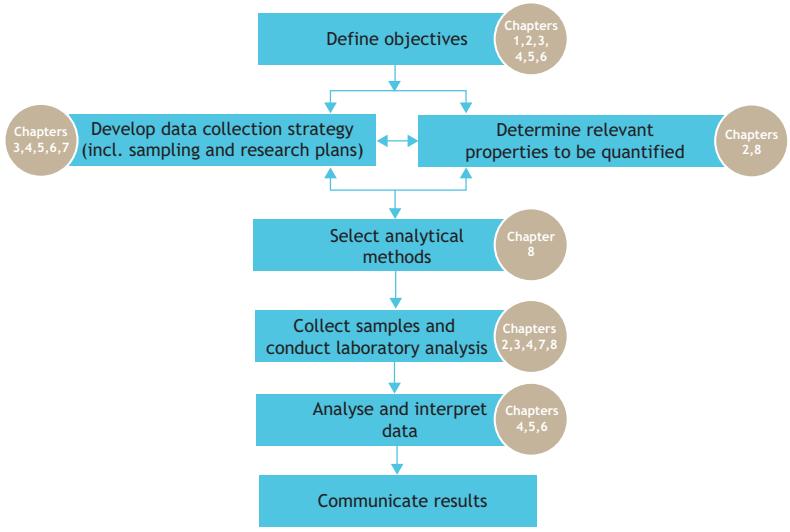

Figure 1.5 The integrated approach to data collection and analysis presented in this book, and relevant chapters at each step of the integrated process.

Table 1.1 Objectives of book chapters.

Chapter 1: Setting the stage • Introduce city-wide inclusive sanitation (CWIS) • Define faecal sludge • Explain the need for standard methods • Provide an overview of the book chapters • Present additional resources	**Chapter 2: Faecal sludge properties and considerations for characterisation** • Present four types of faecal sludge depending on total solids content • Provide a brief overview of factors that can influence characteristics of faecal sludge along the service chain. • Explain the relevance of selecting different faecal sludge properties based on the objectives of characterisation • Explain factors for consideration when selecting characterisation methods • Provide guidelines for setting up faecal sludge laboratories, along with case studies of existing implementations
Chapter 3: Faecal sludge sample collection and handling • Select different sampling techniques depending on objectives • Select sampling devices and locations • Develop appropriate and reliable faecal sludge sampling schemes and plans • Ensure sample representativeness and integrity • Protect health and safety of employees and users of onsite sanitation	**Chapter 4: Experimental design for the development, transfer, scaling-up, and optimisation of treatment technologies: case studies of dewatering and drying** • Introduce scales of experimentation and experimental design for the development, transfer, scaling-up, and optimisation of faecal sludge treatment technologies • Provide examples of experimental approaches for scaling-up conditioners for dewatering and drying for resource recovery • Present case studies that address research questions at different scales of faecal sludge treatment processes and technology development and adaptation
Chapter 5: Estimating quantities and qualities (Q&Q) of faecal sludge at community to city-wide scales • Explain the importance of being able to reasonably estimate Q&Q of faecal sludge • Define the six stages in the faecal sludge service chain where Q&Q of faecal sludge can be estimated • Summarise the existing state of knowledge and future prospects for making projections of Q&Q of faecal sludge • Provide an overview of a methodology to estimate Q&Q of faecal sludge on a scale relevant for the planning of management and treatment solutions, from community scale to city-wide planning	**Chapter 6: Towards city-wide inclusive sanitation (CWIS) modelling: modelling of faecal sludge containment/treatment processes** • Promote modelling of onsite sanitation • Familiarise readers with the basic principles of established modelling approaches applied in sewered sanitation • Introduce ideas on how faecal sludge containment/treatment processes can be modelled using the analogy with modelling practices in sewered sanitation • Bring sewered and onsite sanitation closer together through the integrated approach of community city-wide inclusive sanitation modelling
Chapter 7: Faecal sludge simulants: review of synthetic human faeces and faecal sludge for sanitation and wastewater research • Introduce the concept of simulants and their applications • Present current state-of-the-art knowledge in simulants for faecal sludge, faeces and urine • Compare properties between simulants and typical values observed in the field • Introduce customisation of simulants, including advantages and constraints	**Chapter 8: Laboratory procedures and methods for characterisation of faecal sludge** • Provide methods for protecting health and safety during collection, handling, transportation, storage, and disposal of faecal sludge • Provide information required to adapt and develop standard methods for faecal sludge characterisation, including quality control and quality assurance strategies and selection of appropriate methods. • Provide an overview of existing methods for faecal sludge analysis being used in partner laboratories.

1.5 ADDITIONAL RESOURCES

The editors of this book came together for this project because their research, field, and teaching experience identified the need for standard methods for faecal sludge analysis. This open access book addresses that gap, and it can now be used by practitioners, designers, researchers, students, and teachers as an integrated resource. However, *Methods for Faecal Sludge Analysis* is not intended to be used as a stand-alone reference, but to be used as a companion guide to existing publications, face-to-face teaching, and online courses. Fortunately, over the last decade available tools and references for faecal sludge management have become increasingly available. The editors have assembled a list of additional sanitation resources that are available, with particular focus on faecal sludge management. This includes textbooks and manuals, massive online open courses (MOOCs), online and short courses, professional certificate/diploma programs, undergraduate and postgraduate university curricula, tailor-made training courses, conferences and events, networks, partnerships, toolboxes, toolkits, software, and some key global sanitation/FSM initiatives. The list is not by any means exhaustive or final, and will be regularly updated and expanded in the online version of this book on the GPLFSA website.

Textbooks and manuals

- Faecal sludge management: Systems approach for implementation and operation (Strande *et al.,* 2014)[3,4] available in several languages[5]
- Faecal sludge management: Highlights and exercises (Englund and Strande, 2019)[6]
- Compendium on sanitation systems and technologies (Tilley *et al.,* 2014)[7] available in several languages[8]
- Guidelines for community-led urban environmental sanitation planning (CLUES) (Lüthi *et al.,* 2011)[9]
- Sanitation 21: A planning framework for improving city-wide sanitation services (Parkinson *et al.,* 2014)[10]
- How to design wastewater systems for local conditions in developing countries (Robbins and Ligon, 2014)[11]
- Hygiene and sanitation software - An overview of approaches (Peal *et al.,* 2010)[12]
- Regenerative sanitation (Koottatep *et al.,* 2019)[13]
- Compendium of global good practices – Urban Sanitation (NIUA, 2015)[14]
- Faecal sludge and septage treatment (Tayler, 2018)[15]
- Guidelines on sanitation and health (WHO, 2018)[16]
- Resource recovery from waste (Otto and Drechsel, 2018)[17]
- Innovations for urban sanitation (Myers *et al.,* 2018)[18]
- Sustainable sanitation for all (Bongartz *et al.,* 2016)[19]
- Organic waste recycling: technology, management and sustainability (Polprasert and Koottatep, 2017)[20]

[3] https://www.eawag.ch/en/department/sandec/publications/fsm-book/
[4] https://www.un-ihe.org/sites/default/files/fsm_book_lr.pdf
[5] English, French, Spanish, Marathi, Tamil and Hindi
[6] https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/FSM_Book_Highlights_and_Exercises/FSM_Highlights_and_Exercises_Final-compressed.pdf
[7] https://www.eawag.ch/en/department/sandec/publications/compendium/
[8] English, French, Spanish, Arabic, Nepali, Russian, Vietnamese, Korean and Romanian
[9] https://www.eawag.ch/en/department/sandec/projects/sesp/clues/
[10] https://www.eawag.ch/en/department/sandec/
[11] https://iwaponline.com/ebooks/book/385/How-to-Design-Wastewater-Systems-for-Local
[12] https://www.wsscc.org/resources-feed/hygiene-sanitation-software-overview-approaches/
[13] https://www.iwapublishing.com/books/9781780409672/regenerative-sanitation-new-paradigm-sanitation-40
[14] https://pearl.niua.org/sites/default/files/books/GP-GL2_SANITATION.pdf
[15] https://www.susana.org/_resources/documents/default/3-3439-7-1540380071.pdf
[16] https://www.who.int/water_sanitation_health/publications/guidelines-on-sanitation-and-health/en/
[17] http://www.iwmi.cgiar.org/Publications/Books/PDF/resource-recovery-from-waste.pdf
[18] https://practicalactionpublishing.com/book/1139/innovations-for-urban-sanitation
[19] https://practicalactionpublishing.com/book/2130/sustainable-sanitation-for-all
[20] https://practicalactionpublishing.com/book/693/faecal-sludge-and-septage-treatment

- Compendium of sanitation technologies in emergencies (Gensch *et al.,* 2018)[21]
- Resource recovery and reuse series (IWMI series)[22]
- Co-treatment of septage and faecal sludge in sewage treatment facilities (Narayana, 2020)[23]
- Experimental methods in wastewater treatment (Van Loosdrecht *et al.,* 2016)[24] available in several languages[25]

MOOCs / Online courses

- Water supply and sanitation policy in developing countries[26]
- Planning and design of sanitation systems and technologies[27]
- Introduction to faecal sludge management[28]
- Foundations of public health practice: Health protection[29]
- Water supply and sanitation policy in developing countries[30]
- Public health in humanitarian crises[31]
- Introduction to public health engineering in humanitarian contexts[32]
- Municipal solid waste management in developing countries[33]
- Planning and design of sanitation systems and technologies[34]
- Water - Addressing the global crisis[35]
- Faecal sludge management[20,36,37,38,39,40,41]
- Faecal sludge management online course[42]
- Experimental methods in wastewater treatment series[43]
- Sanitation systems and services[44]
- Sanitation and public health[44]
- Sanitation technology[44]
- Sanitation governance[44]
- Sanitation financing[44]
- Behaviour change and advocacy[44]
- Emergency sanitation[44]
- Analysis of sanitation flows[44]
- Various online courses on non-sewered sanitation[44]

---

[21] http://washcluster.net/emersan-compendium
[22] https://www.iwmi.cgiar.org/publications/resource-recovery-reuse/
[23] https://www.iwapublishing.com/books/9781789061260/co-treatment-septage-and-faecal-sludge-sewage-treatment-facilities
[24] https://www.iwapublishing.com/books/9781780404745/experimental-methods-wastewater-treatment
[25] English, Spanish, Croatian, Russian, Marathi and Hindi
[26] http://www.cltsfoundation.org/massive-online-open-courses-moocs-water-supply-sanitation-policy-developing-countries/
[27] https://www.mooc-list.com/course/planning-design-sanitation-systems-and-technologies-coursera
[28] https://www.eawag.ch/en/department/sandec/e-learning/moocs/, in English, Portuguese, Spanish, French, Hindi and Bengali
[29] https://www.mooc-list.com/course/foundations-public-health-practice-health-protection-coursera
[30] https://www.mooc-list.com/course/water-supply-and-sanitation-policy-developing-countries-part-1-understanding-complex-problems
[31] https://www.mooc-list.com/course/public-health-humanitarian-crises-coursera, in English, Portuguese, French, Spanish, Hindi, Indonesian and Arabic
[32] https://www.mooc-list.com/course/introduction-public-health-engineering-humanitarian-contexts-coursera
[33] https://www.eawag.ch/en/department/sandec/e-learning/moocs/
[34] https://www.eawag.ch/en/department/sandec/e-learning/moocs/, in English, Portuguese, French, Spanish, Hindi, Bengali and Russian
[35] https://www.siwi.org/watercourse/
[36] https://www.un-ihe.org/online-course-faecal-sludge-management
[37] https://sanitationeducation.org/courses/faecal-sludge-management/
[38] https://www.fsmonlinecourse-ait.com/
[39] http://prg.ukzn.ac.za/fsm-on-line-course
[40] http://cseindia.org/fsm/onlinecourse.html
[41] http://www.2ie-edu.org/index.php/fr/?page_id=1989
[42] https://www.lboro.ac.uk/research/wedc/news/news/fsm-online-course.html
[43] https://experimentalmethods.org/
[44] https://sanitationeducation.org/online-courses/

Short courses

- Sanitation systems and services[45]
- Sanitation and public health[45]
- Sanitation technology[45]
- Sanitation governance[45]
- Sanitation financing[45]
- Behaviour change and advocacy[45]
- Emergency sanitation[45]
- Analysis of sanitation flows[45]
- Non-sewered sanitation[45,46,47]
- Faecal sludge management in India[48]
- Various short courses on non-sewered sanitation[49]

Professional diploma programs

- Graduate Professional Diploma Program (GPDP) in Sanitation and Sanitary Engineering[50,51]
- Various GPDP programs on non-sewered sanitation[52]

Undergraduate / postgraduate programs

- MSc in Sanitation[53]
- ME Sanitation Science Technology and Management[54]
- MSc in Sanitation[55]
- MS/ME in Sanitation Technology[56]
- MTech in Non-Sewered Sanitation[57]
- MSc in Non-Sewered Sanitation[58]
- MSc in Water Supply and Sanitation Management[59]
- MSc in Sanitary Engineering[60]
- Various postgraduate programs on sanitation[61]

Tailor-made training courses

- Consultant capacity development (ConCaD) for city-wide inclusive urban sanitation[62]
- Non-sewered sanitation[63]
- Training the trainers in MOOC development[64]
- FSM toolbox training[65]

---

[45] http://enpho.org/
[46] https://www.ku.edu.np/
[47] https://www.ukgllp.com/
[48] https://cddindia.org/network
[49] https://sanitationeducation.org/on-campus-courses/
[50] https://sanitationeducation.org/gpdp/
[51] https://www.un-ihe.org/urban-water-and-sanitation
[52] https://sanitationeducation.org/gpdp/
[53] https://sanitationeducation.org/master-program/master-science-program-sanitation/
[54] https://www.bits-pilani.ac.in/goa/biologicalScience/GSGS
[55] http://gsgs-kuet.education/
[56] http://gsgs.ku.edu.np/
[57] https://jaipur.manipal.edu/foe/programs/program-list/MTech-Non-Sewered-Sanitation.html
[58] http://www.2ie-edu.org/index.php/fr/presentation/projets-et-dons/projet-de-master-specialise-en-assainissement-non-collectif
[59] https://gsgs-ina.itb.ac.id/
[60] https://www.un-ihe.org/msc-programmes/specialization/sanitary-engineering-0
[61] https://sanitationeducation.org/msc-in-sanitation/
[62] https://www.eawag.ch/en/department/sandec/projects/sesp/consultant-capacity-development-concad-for-city-wide-inclusive-urban-sanitation/
[63] http://www.2ie-edu.org/index.php/fr/?page_id=1989
[64] http://www.2ie-edu.org/index.php/fr/?page_id=1989
[65] https://www.ait.ac.th/

- Training on non-sewered sanitation in India[66]
- Novel sanitation in India[67]

Conferences / events

- WEDC international conference[68] (since 1973)
- IWA Water and Development Congress and Exhibition[69] (since 2009)
- FSM conference[70] (since 2011)
- IWA Non-sewered Sanitation Conference[71] (starting in 2021)
- AfricaSan conference[72] (since 2008)
- AfWA International Conference and Exhibition[73] (since 2002)

Networks

- Sustainable Sanitation Alliance (SuSanA)[74]
- Faecal Sludge Management Alliance (FSMA)[75]
- IWA specialist groups, *e.g.* Non-Sewered Sanitation, Sanitation and Water Management in Developing Countries, Resources Oriented Sanitation[76]
- National Faecal Sludge and Septage Management Alliance (NFSSMA)[77]
- African Water Association (AfWA)[78]
- Toilet Board Coalition[79]
- Container-based Sanitation Alliance[80]
- Women in Water and Sanitation Network[81]
- Water Supply and Sanitation Collaborative Council[82]
- Asia-Pacific Water Forum[83]

Partnerships

- Global Sanitation Graduate School (GSGS)[84]
- Global Partnership of Laboratories of Faecal Sludge Analysis (GPLFSA)[85]
- Global WASH Cluster[86]

Toolboxes / toolkits / software

- FSM Toolbox[87]
- Sustainable sanitation and water management toolbox[88]

---

[66] https://asci.org.in/
[67] https://www.bits-pilani.ac.in/
[68] https://www.lboro.ac.uk/research/wedc/conferences/
[69] https://iwa-network.org/events/iwa-water-and-development-congress-exhibition-2019/
[70] https://fsm-alliance.org/fsm6/
[71] https://iwa-network.org/events/1st-iwa-non-sewered-sanitation-conference-21-to-24-july-2020-future-africa-campus-university-of-pretoria-pretoria-south-africa/
[72] https://www.africasan.com/
[73] https://www.africasan.com/africasan
[74] https://www.susana.org/en/
[75] https://fsm-alliance.org/
[76] https://iwa-network.org/wp-content/uploads/2015/12/IWA-Specialist-Groups-2018_A4.pdf
[77] https://www.washinstitute.org/nfssm.php
[78] https://www.afwa-hq.org/index.php/fr/
[79] https://www.toiletboard.org/
[80] http://www.cbsa.global/#/
[81] http://wwsn.org
[82] https://www.wsscc.org
[83] http://apwf.org/
[84] https://sanitationeducation.org/
[85] https://sanitationeducation.org/laboratories/
[86] http://washcluster.net/
[87] https://www.fsmtoolbox.com/
[88] https://www.sswm.info/

- Shit (excreta) flow diagram (SFD)[89]
- SaniPath[90]
- SanI-Kit[91]
- SaniPlan[92], SaniTab[92], FSM assessment and planning toolkit[92], Performance assessment toolkit[92], Open defecation free cities model[92], Target-setting model[92], SBM support tool for infrastructure and financial requirement calculations[92], PSP toolkit for IFSM[92]
- World Bank FSM tools[93]
- The Sphere emergency training toolkit[94]

Other initiatives

- Reinvent the Toilet Challenge[95]
- Health, safety and dignity of sanitation workers - WaterAid, World Bank, the World Health Organisation and the International Labour Organisation
- Sanitation Technology Platform (STeP)[96]
- Engineering field testing platform of innovative toilet technologies[97]
- South African Sanitation Technology Demonstration Programme (SASTEP)[98]
- ISO Standards for non-sewered sanitation: ISO 30500, ISO 24521, and ISO PC 318[99]
- Pit emptying challenge under World Skills
- The World Bank[100]
- Asian Development Bank[101]
- Inter-American Development Bank[102]
- African Development Bank[103]
- Islamic Development Bank[104]
- European Bank for Reconstruction and Development[105]
- Bill & Melinda Gates Foundation[106]

[89] https://sfd.susana.org/
[90] http://sanipath.org/
[91] https://www.cseindia.org/sanikit/index.html
[92] https://www.pas.org.in/web/ceptpas/urbansanitation
[93] https://www.worldbank.org/en/topic/sanitation/brief/fecal-sludge-management-tools
[94] https://www.spherestandards.org/resources/the-sphere-emergency-training-toolkit/
[95] https://www.gatesfoundation.org/Media-Center/Press-Releases/2012/08/Bill-Gates-Names-Winners-of-the-Reinvent-the-Toilet-Challenge
[96] https://stepsforsanitation.org/
[97] https://www.susana.org/en/knowledge-hub/projects/database/details/474
[98] https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/2201
[99] https://sanitation.ansi.org/
[100] https://www.worldbank.org/en/topic/sanitation
[101] https://www.adb.org/sectors/water/financing-program/sanitation-wastewater-management
[102] https://www.iadb.org/en/sector/water-and-sanitation/overview
[103] https://www.afdb.org/en/topics-and-sectors/sectors/water-supply-sanitation
[104] https://www.isdb.org/sector/sanitation
[105] https://www.ebrd.com/what-we-do.html
[106] https://www.gatesfoundation.org/what-we-do/global-growth-and-opportunity/water-sanitation-and-hygiene

REFERENCES

Andriessen N., Ward B.J. and Strande L. (2019). To char or not to char? Review of technologies to produce solid fuels for resource recovery from faecal sludge. *Journal of Water, Sanitation and Hygiene for Development*, 9(2), 210-224.

Dodane P.H., Mbéguéré M., Ousmane S. and Strande L. (2012). Capital and Operating Costs of Full-Scale Faecal Sludge Management and Wastewater Treatment Systems in Dakar, Senegal. *Environmental Science & Technology.* 46(7), 3705-3711.

Englund M., Carbajal J.P., Ferré A., Bassan M., Vu T.H.A., Nguyen V.A. and Strande L. (2020. Modelling quantities and qualities (Q&Q) of faecal sludge in Hanoi, Vietnam and Kampala, Uganda for improved management solutions. *Journal of Environmental Management*, 261, 110202.

Englund M. and Strande L. (eds.) (2019). Faecal Sludge Management: Highlights and Exercises. ISBN 978-3-906484-70-9, Eawag: Swiss Federal Institute of Aquatic Science and Technology. Dübendorf, Switzerland. www.sandec.ch/fsm-hebook

Gambrill M., Gilsdorf R.J. and Kotwal N. (2020). Citywide Inclusive Sanitation - Business as Unusual: Shifting the Paradigm by Shifting Minds. *Front. Environ. Sci.,* 11, doi.org/10.3389/fenvs.2019.00201.

Gold M., Dayer P., Faye C., Clair G., Seck A., Niang S., Morgenroth E. and Strande L. (2016). Locally produced natural conditioners for dewatering of faecal sludge. *Environmental Technology*, 1-13.

Gold M., Harada H., Therrien J.-D., Nishida T., Cunningham M., Semiyaga S., Fujii S., Niwagaba C., Dorea C., Nguyen V.-A. and Strande L. (2018). Cross-country analysis of faecal sludge dewatering. *Environmental Technology*, 1-11.

Henze M., Van Loosdrecht M.C.M., Ekama G.A. and Brdjanovic D. (2008). Biological Wastewater Treatment - Principles, Modelling and Design, 1st ed. IWA Publishing, London, UK.

Hiolski E. (2019). The Toilet Gets a Makeover, How chemistry can help solve the sanitation crisis in low-resource areas. *ACS Central Science,* 5(8), 1303–1306.

Jenkins D. and Wanner J. (eds.) (2014). Activated Sludge - 100 Years and Counting. IWA Publishing. London, UK.

Klinger M., Gueye A., Manandhar Sherpa A. and Strande L. (2019). Scoping Study: Faecal Sludge Treatment Plants in South-Asia and Sub-Saharan Africa. eFSTP Project Report. *Gates Open Research* 2019, 3, 1716 (document) (https://doi.org/10.21955/gatesopenres.1116557.1)

Klute A. (ed.) (1986). Methods of soil analysis. Part 1 Physical and mineralogical properties. Madison, WI: American Society of Agronomy; Crop Science Society of America; Soil Science Society of America.

Narayan A.S., Marks S.J., Meierhofer R., Strande L., Tilley E., Zurbrügg C. and Lüthi C. (2021). Advancements in and Integration of Water, Sanitation and Solid Waste in Low and Middle Income Countries. Annual Review of Environment and Resources.

Otoo M. and Drechsel P. (eds.) (2018). Resource recovery from waste: business models for energy, nutrient and water reuse in low- and middle-income countries. Oxon, UK: Routledge - Earthscan.

Page A.L. (ed.) (1983). Methods of Soil Analysis Part 2 Microbiological and Biochemical Properties. Madison, WI: American Society of Agronomy; Crop Science Society of America; Soil Science Society of America.

Peal A., Evans B., Sangaralingam A., Ban R., Blackett I., Hawkins P., Schoebitz L., Scott R., Sleigh A., Strande L. and Roda O. (2020). Estimating safely managed sanitation in urban areas, lessons learned from a global implementation of excreta-flow diagrams. *Front. Environ. Sci.,* https://doi.org/10.3389/fenvs.2020.00001.

Rice E.W., Baird R.B. and Eaton A.D. (eds.) (2017). Standard Methods for the Examination of Water and Wastewater, 23rd edition. American Public Health Association; American Water Works Association; Water Environment Federation. ISBN: 9780875532875.

Schrecongost A., Pedi D., Rosenboom J.W., Shrestha R. and Ban R. (2020). Citywide Inclusive Sanitation: A Public Service Approach for Reaching the Urban Sanitation SDGs. *Front. Environ. Sci.* 8, 1-8. doi:10.3389/fenvs.2020.00019.

Sparks D.L., Page A.L., Helmke P.A., Loeppert R.H., Soltanpour P.N., Tabatabai M.A., Johnston C.T. and Sumner M.E. (eds.) (1996). Methods of Soil Analysis Part 3 Chemical methods. Madison, WI: American Society of Agronomy; Crop Science Society of America; Soil Science Society of America.

Strande L., Ronteltap M. and Brdjanovic D. (eds.) (2014). Faecal Sludge Management - Systems Approach for Implementation and Operation. IWA Publishing, London, UK, doi:10.1007/s13398-014-0173-7.2.

Tchobanoglous G., Stensel H.D., Tsuchihashi R. and Burton F. (2014). Wastewater Engineering: Treatment and Resources Recovery, 5th edn. New York, NY: McGraw-Hill Education.

Tilley E., Ulrich L., Lüthi C., Reymond P. and Zurbrügg C. (2014). Compendium of Sanitation Systems and Technologies. 2nd edn. Eawag: Swiss Federal Institute of Aquatic Science and Technology.

Von Sperling M., Verbyla M.E. and Oliveira S.M.A.C. (2020). Water Quality Data: A Guide for Students, Researchers and Practitioners. IWA Publishing, London, U.K.

Wagner E.G. and Lanoix J.N. (1958). Excreta disposal for rural areas and small communities. World Health Organisation Publication, Geneva, Switzerland.

Ward B.J., Gueye A., Diop B., Traber J., Morgenroth M. and Strande L. (2019). Evaluation of conceptual model and predictors of faecal sludge dewatering performance in Senegal and Tanzania. *Water Research,* 167, 115101.

World Health Organisation (2018). Guidelines on sanitation and health. ISBN 978-92-4-151470-5. World Health Organisation, Geneva, Switzerland.