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Guidelines and Regulations for Fecal Sludge Management from On-site Sanitation Facilities

Nilanthi Jayathilake, Pay Drechsel, Bernard Keraita, Sudarshana Fernando and Munir A. Hanjra (†)



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RESOURCE RECOVERY & REUSE SERIES 14

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Nilanthi Jayathilake, Pay Drechsel, Bernard Keraita, Sudarshana Fernando and Munir A. Hanjra (†)

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Front cover photograph: Informal fecal sludge management in Guntur, India (*photo*: C.S. Sharada Prasad).

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ACRONYMS AND ABBREVIATIONS

AAR	Annual Application Rate
BOD	Biological Oxygen Demand
CBO	Community-based Organization
CFR	Code of Federal Regulations
COD	Chemical Oxygen Demand
CSO	Civil Society Organization
CU	Commercial Utility
EPA	Environmental Protection Agency
EU	European Union
FS	Fecal Sludge
FSM	Fecal Sludge Management
FSSM	Fecal Sludge and Septage Management
GW	Groundwater
MDG	Millennium Development Goal
MOECC	Ministry of the Environment and Climate Change (Canada)
MSW	Municipal Solid Waste
N	Nitrogen
NGO	Nongovernmental Organization
NWASCO	National Water Supply and Sanitation Council (Zambia)
O&M	Operation and Maintenance
OHS	Occupational Health and Safety
OSS	On-site Sanitation Systems
PAH	Polyaromatic hydrocarbon
PFC	Perfluorinated compound
PPE	Personal Protective Equipment
RRR	Resource Recovery and Reuse
SDG	Sustainable Development Goal
STP	Sewage Treatment Plant (= WWTP)
TS	Transfer Stations
ULB	Urban Local Body (India)
UNICEF	United Nations Children's Fund
VOC	Volatile Organic Compound
WHO	World Health Organization
WSS	Water Supply and Sanitation
WWTP	Wastewater Treatment Plant (= STP)
USEPA	United States Environmental Protection Agency
ZABS	Zambia Bureau of Standards
ZEMA	Zambia Environmental Management Agency

SUMMARY

The Sustainable Development Goal (SDG) indicator 6.2.1 seeks to provide universal safely managed sanitation services. This applies to areas such as city centers where sewer systems commonly offer the locally best solution as well as to on-site sanitation systems (OSS), such as septic tanks or pit latrines, which remain the most sustainable alternative in other areas. Globally, 2.7 billion people depend on these OSS, and this number is expected to grow to five billion by 2030. Across and within most low- and middle-income countries, fecal sludge management (FSM) from on-site systems has received little attention over many decades resulting in limited resources, transport and treatment capacities, unsystematic and poor planning, and insufficient or lack of regulations to guide investments and management options.

To address this gap, this report examines existing and emerging guidelines and regulations for FSM along the sanitation service chain (user interface, containment, emptying, transport, treatment, valorization, reuse or disposal) with empirical examples drawn from guidelines across the globe. The objective is to support policy-makers, planners, sanitation and health officers as well as consultants in low- and middle-income countries in the development and design of local and national FSM guidelines and regulations. The report ends with a related framework for the development of such documents, giving special attention to resource recovery and reuse (RRR).

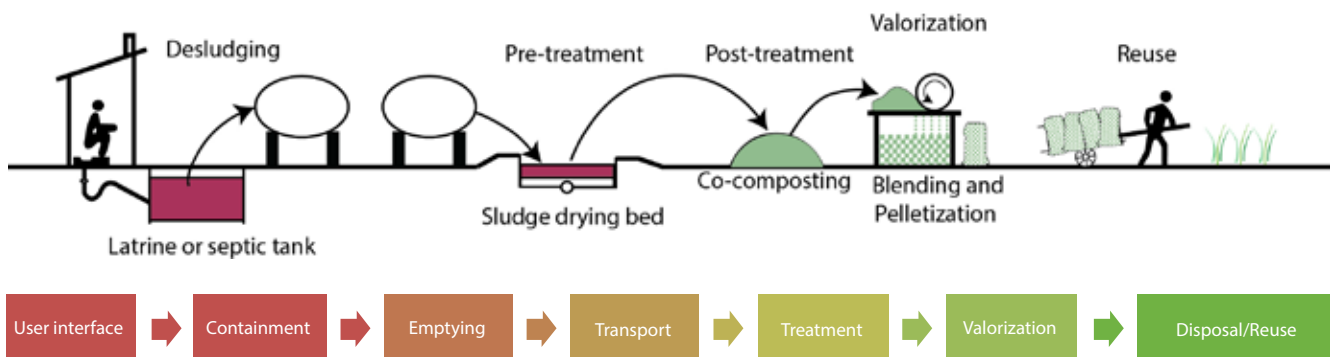
1. INTRODUCTION

Globally, a large share of urban dwellers and almost all rural dwellers rely on non-sewered (on-site) sanitation systems (OSS), especially, but not only, in the context of low-income countries (Cairns-Smith et al. 2014). OSS retain wastes in the vicinity of the household in a pit, septic tank or vault (containment). Once the OSS storage tank reaches its functional capacity, it needs to be emptied. The collected mix of solid and liquid human waste from OSS is generally termed fecal sludge (FS) and can be partially fresh or raw, partially digested, ranging from very liquid to nearly solid consistency. Broadly, FS can be defined as combinations of excreta (feces and urine) and toilet flushing water, with or without greywater from other household units. Due to various climatic conditions, cultural contexts, OSS type and so forth, the consistency and characteristics of FS can vary highly (see Section 4.1, Table 10) among regions, countries

and even within the same locality. Such variation can strongly influence its management options, hazards, occupational and community exposure as well as risk characterization, which have to be accounted for in related regulations and guidelines.

Fecal sludge management (FSM) has always been a challenge in thinly populated rural areas where sewer pipelines are far too costly, but also in rapidly growing cities where infrastructure development has been outpaced by population growth and housing development. Today, about 2.7 billion people rely on OSS, a number that is expected to grow to five billion by 2030 (Strande et al. 2014). Consequently, there is the potential for significant negative impacts on public health and the environment unless well-regulated service chains are in place (Figure 1).

FIGURE 1. SANITATION VALUE CHAIN.



Source: Modified from Keraita et al. 2014

This service chain perspective is the basis of the United Nations’ Sustainable Development Goal (SDG) indicator 6.2.1, which targets the “proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water”. The indicator builds on (and extends beyond the toilet) the Millennium Development Goal (MDG) target 7.C “to halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation”.

Based on the former MDG target, low-income countries prioritized hygiene, eradicating open defecation and providing access to improved toilet facilities. The SDG target goes several steps further to pay due attention to the entire sanitation service chain. This is needed to further eliminate the risk of exposure to excreta-borne pathogens ‘once the pit is full’, i.e., along the FSM pathway. Once collected, the most common FS disposal methods in low-income countries unfortunately still remain as discharge into excavated pits, storm drains, sewers, surface water bodies, or dumping in forested areas, vacant land and very commonly, in solid waste landfills.

In fact, across most developing countries, FSM appears to be unsystematic and unplanned, which is reflected in the general paucity of related data, any governing policy or regulatory framework. One reason might be that for a long time on-site sanitation was considered an interim solution toward an all-sewered situation, and only recently has its cost competitiveness been recognized, e.g., in regions with low population densities or without sufficient water to flush sewers (Cairns-Smith et al. 2014). As a result of limited attention, **FS collection services are often provided by the informal sector without adequate technology, regulations and safety precautions.** Options for resource recovery are seldom considered (Blackett et al. 2014). The negative impacts of

insufficient and unsustainably managed FS are well known so FSM remains a critical and urgent need that must be addressed (WHO 2006b; Strande et al. 2014).

Within this context, the need for official recognition, support and **regulatory guidance** for safe and sustainable FSM is urgent. In India, for example, the government issued the National Policy for Fecal Sludge and Septage Management in 2017, and an increasing number of Indian states now have FSM policies or regulations in place, or in various stages of preparation.

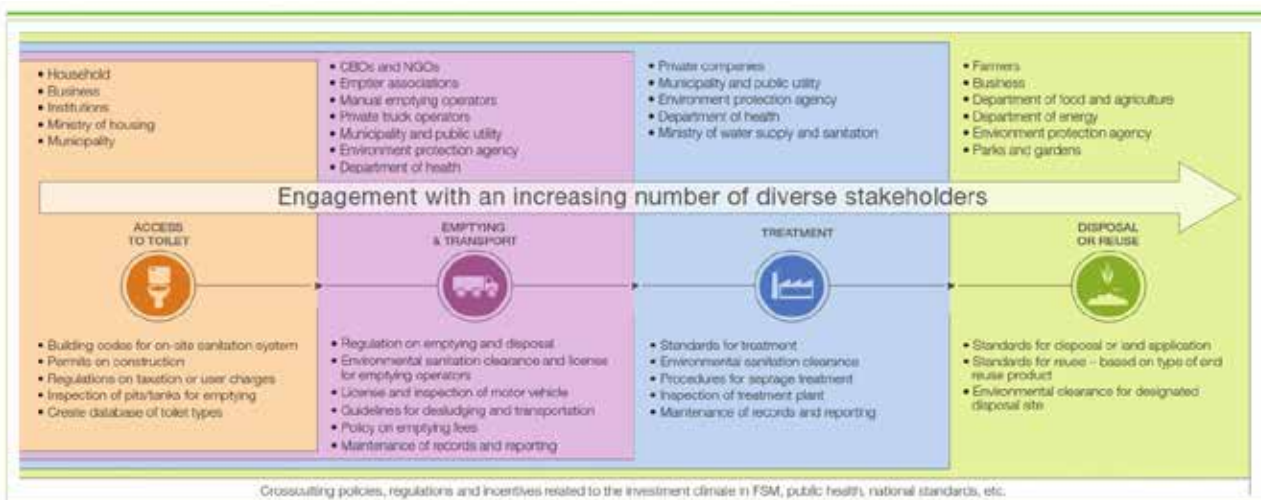
This report presents a review of relevant regulatory aspects of FSM, building on examples and technical standards from various countries to be considered when drafting FSM guidelines in a new context, and with due attention to options supporting a circular economy. The report ends with a framework for developing FSM regulations to guide policy-makers, planners as well as sanitation and health officers.

As FSM occurs in the interface of various private and public stakeholders, including authorities in charge of water, health, the environment, housing, urban development and so forth, the number of stakeholders and governing regulations to be considered in FSM regulations is increasing along the sanitation service chain (Figure 2).

A key part of any FSM regulation and its development will therefore be an **analysis of the existing institutional set-up and regulatory framework** to identify and/or revise **roles and responsibilities** while addressing gaps and institutional overlap.

This report draws from various regulations and guidelines across the globe to present examples that could help in the development of similar documents in different locations. Emphasis has been placed on guidance for FS reuse via land application as well as for other purposes (energy, aquaculture).

FIGURE 2. STAKEHOLDERS AND COMMON REGULATIONS ALONG THE SANITATION SERVICE CHAIN.



Source: Rao et al. (2016).

The reader is advised to consult the original or most recent source of any referenced regulation to avoid an ‘out of context’ interpretation. This is also important as terminologies differ among countries, starting with the definitions of FS and septage, which are often (but not always) used interchangeably. It is therefore recommended for any work on policies, regulations and guidelines, **to establish a common terminology** that could later serve as an attached glossary. Examples of glossaries which can guide this step can be found in WHO (2006a, 2006b, 2016), Tilley et al. (2014) and NWASCO (2018).

This report does not address sewage sludge generated in wastewater treatment plants (WWTPs), although the text might refer to treated sewage sludge (or biosolids) that, for example, national legislation addresses in conjunction with septage from OSS.

2. IDENTIFYING ROLES AND RESPONSIBILITIES

As FSM is a task in the interface of various private and public stakeholders, a key requirement of any FSM regulation is the assignment of clear roles and responsibilities. This requires some institutional and

regulatory analysis and allows for different options of visualization. Table 1, which provides an example from India’s National Policy on Fecal Sludge and Septage Management (FSSM), distinguishes between the lead and supportive roles of each institution.

The Zambian example (Table 2) shows a similar analysis along the sanitation service chain, providing additional information and supporting the identification of possible gaps. Figure 3 builds on the same case from Zambia, presenting the policies, regulations, standards, etc. that guide those institutions in the provision of their services, or in other words, the enabling environment along stages of the sanitation service chain.

At the national level, the Government of India (2017) recommended a Sanitation Service Benchmarking framework to assess and monitor performance of citywide sanitation, capturing on-site sanitation systems and sewage management. State Government will be responsible for monitoring and evaluation of its cities’ performance, and hence need to establish data collection and reporting systems for the suggested indicators (Annex). Urban local bodies (ULBs) in turn need to develop databases, register certified on-site sanitation system, and establish robust reporting formats to track compliance of households (establishments, etc.) with outcomes and process standards.

TABLE 1. INSTITUTIONAL ROLES AND RESPONSIBILITIES AROUND FSM IN INDIA.

Institution	Lead role	Supportive role
Ministry of Urban Development	<ul style="list-style-type: none"> • Technical and planning support for states and urban local bodies (ULBs) • Training and capacity building of state-level officials and those from select ULBs • Funding through specific schemes and plans • National-level awareness and behavior change campaigns • Support research and capacity building in the sector • Create an enabling environment for participation of the private sector, nongovernmental organizations (NGOs) and civil society organizations (CSOs) in the provision of FSSM services, including to the poor and marginalized households and areas • National-level monitoring and evaluation 	Formulation of state- and city-level FSSM strategies and implementation plans
Ministry of Environment, Forest and Climate Change	<ul style="list-style-type: none"> • Enforce compliance of the relevant environmental laws and rules during the collection, transport, treatment and disposal of FS and septage 	Support and build capacity of state pollution control toward enforcement of relevant laws and rules
Ministry of Social Justice and Empowerment	<ul style="list-style-type: none"> • Strive toward elimination of manual scavenging and rehabilitation of manual scavengers • Monitor and evaluate progress at the national level • National-level awareness campaigns 	Help states and ULBs to eliminate manual scavenging and rehabilitate manual scavengers

(Continued)

TABLE 1. INSTITUTIONAL ROLES AND RESPONSIBILITIES AROUND FSM IN INDIA. (CONTINUED)

Institution	Lead role	Supportive role
Ministry of Women and Child Development		Gender mainstreaming of information, education and communication material for FSSM across the country
State governments	<ul style="list-style-type: none"> • Develop state-level FSSM strategy and implementation plans • Develop operative guidelines for FSSM • Training and capacity building of ULB officials and others engaged in the provision of FSSM services • State-level awareness and behavior change campaigns • Create enabling environments for participation of the private sector, NGOs and CSOs in provision of FSSM services, including for poor and marginalized households and areas • Funding through specific schemes and plans • Support research and capacity building in the sector • State-level monitoring and evaluation for city Sanitation Service Benchmarking 	<ul style="list-style-type: none"> • Technical, financial and administrative support for ULBs • Encourage coordination and cooperation among ULBs • Regulate and help ULBs to set up systems to ensure financial sustainability in the provision of FSSM services • Implement municipal by-laws
ULBs	<ul style="list-style-type: none"> • Design, develop, plan and implement ULB-level FSSM strategies • Set up and ensure operation of systems for 100% safe and sustainable collection, transport, treatment and disposal of FS and septage • Develop expertise, in-house and outsourced, to provide safe and effective FSSM services • Awareness and behavior change campaigns to engage diverse stakeholders • Develop training programs for masons to build requisite skills in the construction of quality septic tanks according to Bureau of Indian Standards/National Building Code norms • Set up systems to ensure financial sustainability in the provision of FSSM services • Achieve objectives of FSSM policy in a time-bound manner • Design and implement plans to eliminate manual scavenging and rehabilitate manual scavengers • Funding through specific schemes and plans • Database maintenance for Sanitation Service Benchmarking • Implement municipal by-laws 	Create enabling environments for NGOs and private initiatives to achieve safe and sustainable FSSM
Households	<ul style="list-style-type: none"> • Timely and regular cleaning of septic tanks by approved entities • Regular maintenance and monitoring of septic tanks • Timely payment of user fees and/or charges, if any, toward FSSM services • Practice development of by-laws for the construction of OSS 	Engage with decision-makers at state and ULB levels to ensure that they receive good quality FSSM services

Source: Government of India 2017.

TABLE 2. KEY ACTORS AND THEIR ROLES AND RESPONSIBILITIES ALONG THE OSS SERVICE CHAIN IN ZAMBIA.

Stakeholder		Collection	Transport	Treatment	Disposal/ End use
Type	Group				
Government of Republic of Zambia	Ministry of Water Development, Sanitation and Environmental Protection as the lead agency	Policy and laws	Policy and laws	Policy and laws	Policy and laws
Regulating agents	National Water Supply and Sanitation Council (NWASCO) (service provision regulation)	<ul style="list-style-type: none"> Setting OSS construction and FS desludging service standards (with the Zambia Bureau of Standards [ZABS]) Price regulation for emptying of septic tanks, pit latrines and other sanitation facilities 	License for service provision to commercial utilities (CUs)/private operators/community-based organizations (CBOs) (includes price regulation, service quality, consumer protection)	License for CUs and private operators for service provision (includes price regulation for FS treatment and discharge, service quality, consumer protection for FS discharge)	
	Zambia Environmental Management Agency (ZEMA) (environmental protection regulation)		Licensing for environmental protection (in terms of possible damage by transportation vehicles), emptying standards and service quality	<ul style="list-style-type: none"> Licensing for environmental protection Setting FS treatment standards 	Licensing for environmental protection for use of end products
Implementing agents	Local authority	Enforcing standards for on-site facilities/buildings			
Service providers	CU	Monitoring on-site facilities for functionality and service quality	Monitoring operation of transporters	Operation and maintenance (O&M) treatment facilities	
	Private operators	Emptying on-site facilities (includes septic tanks and pit latrines)	Transport FS	O&M treatment facilities (where engaged)	Use of end products
	CBOs	Emptying on-site facilities	Transport FS		
Customers	Non-domestic, community (investors)	<ul style="list-style-type: none"> Building on-site facilities O&M 			Reuse

Source: NWASCO (2018).

FIGURE 3. REGULATION FLOWCHART ALONG THE OSS SERVICE CHAIN IN ZAMBIA.

		Management requirements			Sanitation service chain		
Aspect		Responsibility	Collections	Transport	Treatment	Disposal/ end use	
Political will and government support	Water sector policies and laws	Ministry responsible	<ul style="list-style-type: none"> The Vision 2030 The Water Policy The Water Supply and Sanitation Policy Draft 2016 The Water Supply and Sanitation (WSS) Act of 1997 The National Development Programme (7th to be released) The National Urban Water Supply and Sanitation Programme (2015 to 2030) 		<ul style="list-style-type: none"> The National Water Supply and Sanitation Capacity Development Strategy The National Urban and Peri-Urban Sanitation Strategy The Open Defecation Free strategy 		
	Water sector programs						
	Water sector strategies						
Licensing	Service provision licenses	NWASCO	Stipulates conditions under which the service provider will operate as well as delineation of the service area				
	Emission and waste management licenses	ZEMA	<ol style="list-style-type: none"> Control emission or discharge of pollution or contaminants Control (a) recovery or recycling of waste, (b) collection & disposal of waste from industrial, commercial, domestic or community activities, (c) transportation of waste, (d) ownership, construction or operation of a waste disposal/storage site, and (e) transit, trade or export of waste 				
	Business licenses	Local authority	Businesses operating in Zambia are typically required to obtain one or more licenses and permits, depending on the activities of their enterprises				
Regulations	Standards and code of practice	NWASCO, ZABS, ZEMA	National standards for sanitation facilities established, led by NWASCO. Design and construction by ZABS, limits for environmental protection by ZEMA				
	Building codes	Planning authority of the government	Planning authority establishes building standards in collaboration with NWASCO				
	Statutory requirements	Zambia Revenue Authority, Patents and Companies Registration Agency, National Pension Scheme Authority, Lusaka City Council, etc.					
	Environmental protection regulations	ZEMA	Effluent standards in place. Need to establish FS standards				
	WSS service provision regulations	NWASCO	Service standards for sewerage systems in place. Need to establish service standards and regulations for OSS				

(Continued)

FIGURE 3. REGULATION FLOWCHART ALONG THE OSS SERVICE CHAIN IN ZAMBIA. (CONTINUED)

Management requirements			Sanitation service chain			
Aspect	Responsibility	Collections	Transport	Treatment	Disposal/ end use	
Enforcement	Local authorities	Enforce provision of toilets at every property according to national building standards (can delegate enforcement to CUs according to the WSS Act, 1997)				
Operations	Overall management of the sanitation value chain	Sanitation service chain for sewerage system in place. Need for CUs to manage the sanitation service chain for OSS O&M				
	FS containment	Sanitation facilities built according to national standards/ practice				
	Emptying	Emptying of sanitation facilities ensures protection of the environment and public health				
	Transfer stations (TSs)	CBOs, private, sector CUs	TSs operate to meet ZEMA and NWASCO standards and regulations			
	Transport		Transport of FS meets ZEMA standards and NWASCO service-level standards			
	Treatment			TSs operate to meet ZEMA and NWASCO standards and regulations		
	Disposal/end use				Disposal of FS meets ZEMA standards and NWASCO service levels	

Source: NWASCO (2018, modified).

3. REGULATIONS AND GUIDELINES FOR FECAL SLUDGE CAPTURE AND CONTAINMENT

Usually, the most elaborated part of many FSM regulations concerns the design of toilet systems and their containment. Many countries and various international organizations (e.g., the World Bank, World Health Organization (WHO), United Nations Children's Fund (UNICEF), WaterAid, and the Netherlands Development Organisation (SNV)) have developed or compiled guidelines for OSS; likewise for the design of pit latrines (Box 1) or septic tanks.

To what extent national construction guidelines or building codes are implemented differs, e.g., due to economic and spatial constraints or limited monitoring. Factors steering decision-making at the household level include cost and ease of construction, required space, comfort and privacy

requirements; the household also might consider emptying frequency and availability of the local common tank, cost of the desludging service and so forth. In short, different households can have different preferences and regulations should allow some flexibility. Table 3 shows common OSS a regulation might consider, based on household preferences and traditions as well as technical, health, environmental, economic, climatic or institutional aspects (Franceys et al. 1992). In other words, regulations should not only target the safest or most advanced technical options, but also offer guidance on whatever is already common or could be meaningful in the local household context, which can include a strategy for phasing out certain sanitation options to replace them with more appropriate ones. A second important factor is to plan tank access from the outset. An often-neglected key requirement for any containment option is that it can be physically accessed by the locally available desludging service provider. Septic tanks are often behind houses, placed under toilets, sealed or cemented over, making it difficult to access them for cleaning/emptying, which disincentivizes their frequent cleaning and increases environmental and health risks.

BOX 1. DESIGN EXAMPLES FOR PIT LATRINES.

There are two basic latrine systems: a) when a pit becomes full, it is retired and a second pit is opened (dual pit latrines) or b) the pit is desludged for reuse. The dual pit is a preferred OSS solution in terms of health and safety aspects. However, where capital cost and space are limiting factors, the single pit latrine is the common option.

As a general rule, Franceys et al. (1992) states that pits should be designed to last as long as possible and that a design life of 15 to 20 years is perfectly reasonable. Even pits designed to last 25 to 30 years are not uncommon.

When calculating the dimension of a pit latrine, three conditions must be satisfied:

1. The pit should have sufficient storage capacity for all the sludge that will accumulate during its operational life (during which it cannot be emptied) or before its planned emptying.
2. At the end of the pit's operational life, there should still be sufficient space left for the contents to be covered with a sufficient depth of soil (at least 0.5 meters (m)) to prevent surface contamination with pathogenic organisms (soil seal depth).
3. There should be sufficient wall area at all times to restrict any liquid in the pit from infiltrating into the surrounding soil.

Guidelines for the size of pit latrines (and septic tanks) often recommend a capacity of 3 to 4 cubic meters (m³) for a single household of four members, although much larger pits are common in some areas (USEPA 1999). In South Africa, the recommended pit capacity for ventilated improved pit latrines is 2 to 3 m³, while in some countries, such as Tanzania, pits may be as large as 10 m³.

As a very general guideline it is recommended that the bottom of the pit should be at least 2 m above GW level and a minimum horizontal distance of 30 m between a pit and a water source (such as a well) is recommended to limit exposure to microbial contamination. The optimal distance will however depend on the local hydrogeological subsurface characteristics.

TABLE 3. COMPARISON OF OSS OPTIONS.

Type of latrine	Features	Advantages	Disadvantages
Single pit latrine	<ul style="list-style-type: none"> • Most widely used technology • Should be designed to contain at least 1,000 liters (l) • At least 3 m deep and 1 m in diameter • Construction materials can be brick, rot-resistant timber, concrete, stones or mortar plastered into the soil 	<ul style="list-style-type: none"> • Lowest cost solution • Does not require water for flushing • Does not require permanent superstructure • Low land requirement • Control over carriers and vectors, provided that a tight fitting lid is placed over the hole in the slab • Simplest technology 	<ul style="list-style-type: none"> • Excreta may be visible • Possibility of odor • Possible groundwater (GW) contamination (if the pit is not completely lined) • Cannot have an offset pit • Pit (slab) quality to be ensured to prevent accidents
Ventilated improved pit latrine	<ul style="list-style-type: none"> • Improved version of the single pit latrine; continuous airflow through the ventilation pipe vents odors • The vent pipe should have an internal diameter of at least 110 millimeters (mm) and reach more than 300 mm above the highest point of the toilet superstructure 	<ul style="list-style-type: none"> • Low-cost solution • Does not require water for flushing • Control over carriers and vectors • Less smell in the latrine • Low land requirement • Technology is simple and understandable 	<ul style="list-style-type: none"> • Extra cost for vent pipe and superstructure, and complex construction • Excreta may be visible • Possible GW contamination (if the pit is not completely lined) • Cannot have an offset pit
Pour flush latrine	<ul style="list-style-type: none"> • The pit can be outside the house while the toilet is inside • For offset latrines, the latrine slab does not have to be as strong as that of a latrine with direct access to the pit and so can be thinner 	<ul style="list-style-type: none"> • Limited water use (2–3 l) • Low-cost, affordable solution • Absence of smell in the latrine • Excreta in the pit is not visible • The system effectively reduces levels of odor and carriers/vectors • The system can incorporate an offset pit (can be installed inside a house) • Installation is easy and the system is easy to keep clean 	<ul style="list-style-type: none"> • Only suitable with limited anal cleansing methods • Extra cost for pour flush (i.e., requires reliable water supply) • Requires regular maintenance
Ecological sanitation latrine (often using a urine-diverting dry toilet)	<ul style="list-style-type: none"> • Human excreta are kept dry, i.e., separate from urine, within the toilet • Excreta collected in the chamber (alternatively into two vaults), constructed or placed below the toilet seat, is allowed to decompose for a period of 6–9 months after a chamber is emptied 	<ul style="list-style-type: none"> • Recognizes urine and feces as useful by-products which in return provide users with a low-cost fertilizer and soil conditioner • Reduces pollution problems associated with septage disposal • Does not require water • Control over pathogen carriers and vectors • Safe containment where GW levels are high 	<ul style="list-style-type: none"> • Requires appropriate training of users • Typically, systems do not accept a wide variety of anal cleansing materials • Usually more expensive than simpler latrine types, and partly more inconvenient for the user • May not be practical where reuse is a taboo • May be difficult to introduce (relative to other solutions)
Septic tank	<ul style="list-style-type: none"> • A watertight chamber made of concrete, fiberglass, polyvinyl chloride (PVC) or plastic, through which blackwater and greywater flow for primary treatment • Should have at least two chambers. The first chamber should be at least 50% of the total length, and when there are only two chambers, it should be two-thirds of the total length 	<ul style="list-style-type: none"> • Users have the convenience of a conventional flush toilet • The system reduces the level of odor, flies and other carriers/vectors • Absence of smell in the latrine • Excreta not visible • The system can incorporate an offset pit (can be installed inside a house or outside the compound) 	<ul style="list-style-type: none"> • High cost • Reliable and ample water supply is required • Problems with effluent disposal • Large land requirement for the system (difficult for high-density housing) • Only suitable with limited anal cleansing methods • Limited risks for GW if sealed

(Continued)

TABLE 3. COMPARISON OF OSS OPTIONS. (CONTINUED)

Type of latrine	Features	Advantages	Disadvantages
Aqua privy	<ul style="list-style-type: none"> • A variation of the septic tank • A simple storage and settling tank located directly below the toilet so that the excreta fall into it 	<ul style="list-style-type: none"> • Does not require a constant water supply as the user can defecate directly into the tank • Low-cost form of a septic tank • Reduces odor 	<ul style="list-style-type: none"> • The system can fail to reduce odor if the water seal is not maintained • Water must be available and plentiful • Permeable land is needed to drain the effluent
Container-based sanitation	<ul style="list-style-type: none"> • Excreta collected in sealable, removable containers or cartridges that are transported to treatment facilities • Set-up involves a commercial service which provides toilets and delivers empty containers when picking up full ones 	<ul style="list-style-type: none"> • Suitable for densely populated low-income urban neighborhoods (including slums), emergency camps, social event venues, internally displaced populations • Ideally combined with microwave treatment (irradiation, drying) • Low-cost installment, but service costs • Safe where GW levels are very high • Suitable for ecological sanitation if urine is collected separately (urine-diverting dry toilet [UDDT]) 	<ul style="list-style-type: none"> • Fresh fecal matter poses higher risk to users and workers (unless microwaved) • Fills quickly, fast accumulation rate • Requires frequent emptying/exchange and safe transport

Sources: Adapted and modified from Tilley et al. (2014); Reed et al. (2014); Franceys et al. (1992).

Table 4 highlights the applicability and suitability of the abovementioned OSS. In general, these OSS technologies are applicable in urban, peri-urban and rural contexts. However, some systems are more suitable for high-density settlements and others for low-density areas. Double vault composting toilets, for example, are more applicable in low-density areas and isolated dwellings with adjacent freehold land available, while container-based systems are designed for high-density neighborhoods or slums as well as temporary camps or social events.

From the **public health** perspective, the **FS accumulation rate** is a key parameter when designing and selecting OSS because overflowing tanks pose health risks beyond the household if septage leaks into ground or surface water sources, in the worst

case into the well next door. The accumulation rate is therefore important for selecting the appropriate technology of the right size, and it is closely related to the desludging frequency. Factors influencing the sludge accumulation rate apart from toilet use frequency can be economic (e.g., affordable tank size), technical (the local decomposition rate) or depend on cultural characteristics like the type of anal cleansing material used. Anaerobic decomposition under water produces much greater reduction in volume than aerobic decomposition in air. Anal cleansing materials vary widely around the world, and can require high storage space, in part using a greater volume than the excreta (Franceys et al. 1992). Sludge accumulation data are therefore often specific to local conditions. Generalized accumulation rates (Table 5) can be used in the absence of local data.

TABLE 4. APPLICABILITY AND SUITABILITY OF OSS TECHNOLOGIES.

Sanitation technology	Construction cost	Operating cost	Ease of construction	Self-building potential	Water requirement	Required soil condition	Reuse potential in agricultural applications
Single pit latrine	L	L	Very easy except on wet or rocky ground	H	None	Stable permeable soil: bottom of the pit should be at least 2 m above GW level	L
Ventilated improved latrine	L	L	Very easy except on wet or rocky ground	H	None	Stable permeable soil: 2 m between the bottom of the pit and the GW table is normally recommended	L
Pour flush toilet	L	L	Easy	H	Water near toilet	Stable permeable soil: the bottom of the pit should be at least 2 m above GW level	L
Double vault composting toilet	M	L	Requires some skilled labor	H	None	None (can be built aboveground)	H
Self-topping aqua privy	M	L	Requires some skilled labor	H	Water near toilet	Permeable soil: the bottom of the pit should be at least 2 m above GW level	M
Septic tank	H	H	Requires some skilled labor	L	Water piped to toilet	Permeable soil	M
Container-based sanitation	M	H	Externally provided	Not applicable	None	None	H

Sources: Adapted and modified from Tilley et al. (2014) and Kalbermatten et al. (1980).

Note: L = low; M = medium; H = high.

TABLE 5. SUGGESTED MAXIMUM SLUDGE ACCUMULATION RATES.

Water level and anal cleansing material	Accumulation rate (l capita ⁻¹ year ⁻¹)
Waste retained in water where degradable materials are used (e.g., paper, leaves)	40
Waste retained in water where non-degradable materials are used (e.g., mud, sticks)	60
Waste retained in dry conditions where degradable materials are used	60
Waste retained in dry conditions where non-degradable materials are used	90

Source: Franceys et al. (1992).

Tables 6 and 7 provide guidance on the required capacity of septic tanks, depending on the number of inhabitants, desludging frequencies (all x years) and the addition of other used water, such as laundry water.

TABLE 6. ESTIMATED SEPTIC TANK CAPACITIES IN LITERS (FOR BLACKWATER ONLY).

Number of inhabitants	Pumping intervals in years				
	1	2	3	4	5
Tank capacity (m³)					
3	0.6	0.8	1.1	1.3	1.6
5	0.9	1.3	1.8	2.2	2.6
7	1.3	1.9	2.5	3.1	3.6
10	1.8	2.7	3.5	4.3	5.2

Source: Estimated based on Mara (1996).

TABLE 7. ESTIMATED SEPTIC TANK CAPACITIES IN LITERS (FOR BLACKWATER + WASHING MACHINE WATER).

Number of inhabitants	Pumping intervals in years				
	1	2	3	4	5
Tank capacity (m³)					
3	0.8	1.1	1.5	1.8	2.2
5	1.3	1.9	2.5	3.1	3.6
7	1.8	2.6	3.4	4.3	5.1
10	2.5	3.7	4.9	6.1	7.3

Source: Estimated based on Mara (1996).

Table 8 shows examples of national standards and guidelines that provide regulations and information on the design, construction and operation of different OSS.

Many national OSS guidelines originate from international guidelines or high-income countries where OSS coexist with sewer systems, in particular in rural areas.

TABLE 8. EXAMPLES OF OSS BUILDING CODES AND STANDARDS FROM DIFFERENT COUNTRIES.

Country	Referenced guidelines and legislations
USA	<ul style="list-style-type: none"> • <i>Manual of septic tank practice</i>, U.S. Public Health Service, revised edition 1967. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi/9101V1SI.PDF?Dockey=9101V1SI.PDF • For state specific guidelines see also https://www.epa.gov/septic/advanced-technology-onsite-treatment-wastewater-products-approved-state
Vietnam	<ul style="list-style-type: none"> • <i>Manual for septic tank design, installation and O&M</i> – Ministry of Health • Draft Design Code for Septic Tank Design and Construction — Ministry of Construction <p>Both cited in http://www.susana.org/_resources/documents/default/2-1673-vietnam-fsm-study.pdf</p>
The Philippines	<ul style="list-style-type: none"> • Revised National Plumbing Code of the Philippines. Available at http://www.itnphil.org.ph/docs/sanitation%20-%20wastewater%20-magtibay.pdf
Malaysia	<ul style="list-style-type: none"> • MS1228:1991 – Malaysian Standard Code of Practice for the Design and Installation of Sewerage Systems 1991. Available at https://kupdf.net/download/ms-1228-1991_58c77bccdc0d600452339028_pdf • <i>Malaysian Sewerage Industry Guidelines Vol.5: Septic tanks</i> (2008). Available at https://www.scribd.com/document/378170193/Malaysia-Sewerage-Industry-Guideline-Volume-5 • Malaysian Standard (MS) 2441-1:2012 - <i>On-site sewage treatment units, Part 1: Prefabricated septic tanks specifications</i>. Listed at https://www.jeces.or.jp/spread/pdf/02SPAN5ws.pdf
India	<ul style="list-style-type: none"> • IS 2470: 1985 Code of Practice for Installation of Septic Tanks—Construction of Sludge Containment Facilities. There are two parts to the code: (i) design criteria and construction and (ii) second secondary treatment and disposal of septic tank effluent. Available at http://www.indiawaterportal.org/articles/indian-standard-code-practice-installation-septic-tanks-2470-bureau-indian-standards-1986 • See also <i>Handbook on technical options for onsite sanitation</i> (2012) by the Ministry of Drinking Water and Sanitation. Available at http://mdm.nic.in/mdm_website/Files/WASH/handbook-on_technical-options-for-on-site-sanitation-modws-2012_0.pdf
South Australia	<ul style="list-style-type: none"> • <i>Standard for the construction, installation and operation of septic tank systems in South Australia</i>. Available at https://www.lga.sa.gov.au/page.aspx?u=6640&c=59014
Canada	<ul style="list-style-type: none"> • The Ministry of Municipal Affairs and Housing is responsible for administering septic system approvals as outlined in the Building Code Act. See https://www.ontario.ca/laws/regulation/r12332
Ghana	<ul style="list-style-type: none"> • Ministry of Water Resources, Works and Housing; Community Water and Sanitation Agency. <i>Small towns sector guidelines (Design Guidelines)</i> Vol. III, 2010. Available at http://lgs.gov.gh/index.php/protocols/ (under CWSA's Operational Documents and Guidelines) • <i>Latrine technology manual</i> 2016 (UNICEF supported). Available at https://www.unicef.org/ghana/Latrine_technology_option_manual_final__a4_size.pdf
Sri Lanka	<ul style="list-style-type: none"> • SLS 745 part 1: 2004: Code of Practice for Design and Construction of Septic Tanks and Associated Effluent Disposal Systems. Part 1 — Small Systems Disposing to Ground • SLS 745 part 2: 2009: Code of Practice for the Design and Construction of Septic Tanks and Associated Effluent Disposal Systems. Part 2: Systems Disposing to Surface, Systems for Onsite Effluent Reuse and Larger Systems Disposing to Ground. Available at http://www.slsi.lk/index.php?lang=en (Search Standards with keyword Septic Tanks)

4. REGULATIONS AND GUIDELINES FOR FECAL SLUDGE EMPTYING AND TRANSPORTATION

4.1 Emptying of On-site Sanitation Systems

Essentially, OSS need to be emptied periodically for maintaining their functionality over time, as well as their ability to be emptied (feces harden over time). Table 9 provides typical emptying frequencies of different OSS as reported by the Water Environmental Federation, USA.

There are several techniques available for desludging, ranging from the most basic manual

sludge removal to sophisticated vacuum truck operations (Strande et al. 2014). Rapid urbanization and growing housing densities demand mechanical desludging and sludge removal due to insufficient land area for local FS disposal, but also transport services which can cope with narrow lanes in congested slums areas. There is often no technical alternative to manual cleaning, which can have the advantage of simplicity and low cost, but exposes the involved staff to hazardous health risks. Often, due to the complexity of different types of on-site technologies, economic status and access, a variety of service providers can be found operating simultaneously in any given setting (Strande et al. 2014). Due to different desludging intervals and the availability of water for flushing, the strength of collected FS can vary considerably (Table 10), from watery to high density, which impacts treatment options, like drying bed sizes, and related costs.

TABLE 9. SEPTAGE EMPTYING FREQUENCY AS REPORTED BY THE WATER ENVIRONMENT FEDERATION, USA.

Sanitation systems	Desludging interval
Septic tanks	2–6 years
Cesspool	2–10 years
Privies/portable toilets	1 week to a few months
Aerobic tanks	Up to 1 year
Dry pits (associated with septic fields)	2–6 years

Source: Adapted from USEPA (1999).

Note: Data can vary due to local conditions such as household vs. tank size and do not reflect recommended rates.

TABLE 10. FS CHARACTERISTICS ACROSS 10 CITIES IN INDIA.

Parameter	Unit	Range of all samples	Average of all samples
Oil & grease	mg l ⁻¹	5–156	38
Total phosphorus (as P)	mg l ⁻¹	1–38	10
Kjeldahl nitrogen as N	mg l ⁻¹	85–969	299
Ammonia as NH ₃	mg l ⁻¹	150–972	428
Nitrate as NO ₃	mg l ⁻¹	12.1–39.9	25
Total alkalinity as CaCO ₃	mg l ⁻¹	400–3,403	1,382
pH at 25°C	-	6.32–7.45	6.9
COD	mg l ⁻¹	1,000–67,000	18,500
BOD (3 days)	mg l ⁻¹	600–53,600	13,700
Total solids (TS)	mg l ⁻¹	1,000–103,000	30,800
Total suspended solids	mg l ⁻¹	500–101,000	28,700
MLVSS (mixed liquor volatile suspended solids)	mg l ⁻¹	400–55,900	18,800
Fecal coliforms	MPN 100 ml ⁻¹	110–1,600	426
Helminth eggs	Numbers l ⁻¹	2–45	11

Note: COD = chemical oxygen demand; BOD = biological oxygen demand.

Source: IWMI (unpublished data).

4.2 Specific Guidelines for Inspection and Emptying of Septic Tanks and Pit Latrines

Septic tanks

The septic tank must be accessible for the service providers and their equipment, e.g., access can be provided through a manhole that should not be covered by concrete, roads or flooring and must have a cover which can be removed by an adult only.

Inspection of the filled level: Septic tank inspection every 12 to 18 months is required to ascertain the need for emptying the tank. The sludge and scum levels should be maintained below the design levels in septic tanks to achieve optimum functionality. Hence, the inspection should be directed toward determining the following:

Depth of sludge accumulation at the bottom; and depth of the scum.

A relatively simple check can determine the sludge and scum levels. This check consists of measuring the depths of scum and sludge layers, including assessment of the physical condition of the tank and its components. Inspection can be extended to ensure the baffles are functioning properly and to check for possible leaks (Box 2).

As many households hardly know how (and how often) to inspect their tanks, tank construction and desludging services should support information sharing, for example through leaflets. See for example pages 12 and 13 of the Septic system manual used in Bhutan (MWHS and SNV 2013).

Emptying frequency: Generally, the OSS desludging frequency is based on the OSS type, containment capacity and incoming flow, i.e., the number of toilet users. A common rule is that a septic tank should be emptied when the solids' component of the waste fills between one-half and two-thirds of the tank. Beyond this volume, tanks will still be able to accumulate more sludge but not be able to function as expected and designed. Based on the most common sizes, USEPA (1999) recommended that septic tanks be cleaned, at the least, every five to seven years. However, routine inspection can help to decide if tank cleaning is necessary, rather than enforcing mandatory periodic emptying, which in many countries will have limits due to non-standardized OSS sizes. Furthermore, it is advisable not to empty the septic tanks completely, but to keep a small amount of digesting sludge at the bottom to accelerate the regrowth of biological activities after emptying (Franceys et al. 1992).

BOX 2. TANK DESLUDGING GUIDELINES.

When to desludge: An inspection for sludge layer thickness can determine whether desludging is required. It is recommended that a septic tank must be pumped out

- when sludge and scum occupy half to two-thirds of the tank's working capacity (the tank volume below the outlet pipe invert level);
- every three to five years (sludge hardens over time and is difficult to remove by suction);
- if the bottom of the scum mat is less than 8 centimeters (cm) above the bottom of the baffle/outlet pipe;
- if the minimum working capacity is reached; or
- if the anticipated accumulation rate would result in one of these conditions by the time of the next inspection.

How to desludge: Prior to beginning the desludging procedure, the scum mat is manually broken to facilitate pumping. If the liquid level in the tank is higher than the outlet pipe, the liquid level has to be lowered below the invert of the outlet, which prevents grease and scum from being washed into the drain. Normally, the vacuum/suction hose draws air at a point where 1–2 inches (2.5–5 cm) of sludge remains over the tank bottom, and this material should be retained in the tank. Washing down the inside of the tank is not required unless leakage is suspected and it needs to be inspected. If internal inspection is warranted, fresh air should be continuously blown into the tank for at least 10 minutes before a worker enters.

Sources: USEPA (1994), CSE (2011).

Table 11 shows septic tank pumping intervals as recommended by certain states in the USA as a guide for homeowners to manage their OSS. The intervals can be different in other countries, but the table provides general guidance. The numbers assume that there is no other waste, such as from a kitchen garbage grinder unit, directed to the septic tank.

TABLE 11. ESTIMATED SEPTIC TANK DESLUDGING INTERVALS IN YEARS AS FUNCTION OF HOUSEHOLD SIZE AND TANK CAPACITY.

Tank size (m ³)	Household size (number of people)					
	1	2	3	4	5	6
1.8	5.8	2.6	1.5	1	0.7	0.4
2.8	9.1	4.2	2.6	1.8	1.3	1
3.3	11	5.2	3.3	2.3	1.7	1.3
3.7	12.4	5.9	3.7	2.6	2	1.5
4.6	15.6	7.5	4.8	3.4	2.6	2
5.5	18.9	9.1	5.9	4.2	3.3	2.6
6.5	22.1	10.7	6.9	5	3.9	3.1
7.4	25.4	12.4	8	5.9	4.5	3.7
8.3	28.6	14	9.1	6.7	5.2	4.2
9.2	31.9	15.6	10.2	7.5	5.9	4.8

Note: Tank sizes are rounded (originally in gallons).

Source: Jarret (2004).

Pit latrines

Accessibility: The pit must be accessible for the service providers and their equipment, e.g., it should not be covered by concrete, roads or flooring and must have a cover that can be removed by an adult only.

Inspection of the filled level: The filling status will be invisible in pour flush latrines with water seals, which require the same methodology as used in septic tanks; otherwise, the filling level will be easier to assess.

Emptying frequency: As single pits contain fresh excreta that can cause health and environmental hazards due to pathogen loads and readily biodegradable sludge, special care must be taken in emptying, further treatment and reutilization. In areas where land availability is not a

constraint, it is often advisable to install dual pit latrines, used sequentially. When one pit is almost full (the excreta is 50 cm from the top of the pit), it is covered, and the second pit is used. Once the second pit is filling up, the content of the first pit is removed. Due to the extended resting time (at least one or two years after several years of filling), the material within the older pit is partially sanitized and humus-like. For example, in South Africa, most pits need to be emptied every five to nine years (Still et al. 2012).

Fee structures

The Malaysian Water Association (2017) provides an example of fee structures for domestic, industrial, governmental and commercial stakeholders (Tables 12, 13, 14 and 15). The fee system covers connection to sewerage networks as well as OSS.

TABLE 12. MONTHLY CHARGES FOR DOMESTIC CUSTOMERS (INCLUDING GOVERNMENT QUARTERS) IN MALAYSIA.

Category	Connected charge per month in USD (MYR 1.00 = USD 0.24)
Low-cost houses, houses with annual value of less than MYR 600 and government quarters in categories F, G, H and I (receiving either individual septic tank or connected sewerage services)	0.48
Premises and government quarters with individual septic tanks	1.44
Houses in traditional and new villages and estates (receiving either individual septic tank or connected sewerage services)	0.72
Premises and government quarters in categories A, B, C, D and E receiving connected sewerage services	1.92

TABLE 13. MONTHLY CHARGES FOR INDUSTRIAL CUSTOMERS IN MALAYSIA (EXCLUDING RETAIL AND WHOLESALE).

Category	Rate based on number of employees in USD (MYR 1.00 = USD 0.24)
Premises receiving individual septic tank service	0.48 cap ⁻¹ month ⁻¹
Premises with connected sewerage services	0.60 cap ⁻¹ month ⁻¹

Note: 'Industrial premises' means any building in which the principal activity carried out involves the making, altering, blending, ornamentation, finishing or otherwise treatment or adaptation of any article or substance with a view to its use, sale, transport, delivery or disposal and includes the assembly of parts and ship repairing, but does not include any activity normally associated with retail or wholesale trade.

TABLE 14. MONTHLY CHARGES AND EXCESS RATE CHARGES FOR GOVERNMENTAL PREMISES (EXCLUDING GOVERNMENT QUARTERS) IN MALAYSIA.

Category	Connected charge per month in USD (MYR 1.00 = USD 0.24)
Government premises (flat rate per month)	9.6
Rate on excess volume of water usage per month	Water usage up to 100 m ³ – no extra charge Water usage more than 100 m ³ – 0.11 per m ³ Water usage more than 200 m ³ – 0.24 per m ³

TABLE 15. EXTRA CHARGES FOR EXCESS WATER USE IN COMMERCIAL (TRADE AND BUSINESS) PREMISES IN MALAYSIA.

Band group	Annual value in USD (MYR 1.00 = USD 0.24)	Basic charge in USD (MYR 1.00 = USD 0.24)	
		Connected	Septic tank
1	0–480	1.92	1.68
2	480–1,200	3.36	1.92
3	1,200–2,400	4.80	3.36
4	2,400–4,800	6.24	4.56
5	4,800–7,200	6.96	5.04
6	7,200–9,600	7.68	5.52
7	9,600–12,000	8.40	6.00
8	12,000–14,400	9.12	6.48
9	14,400–16,800	9.84	6.96
10	16,800–19,200	10.56	7.44
11	19,200–21,600	11.28	7.92
12	21,600–24,000	12.00	8.40
13	24,000–48,000	43.20	28.80
14	48,000–96,000	118.80	79.20
15	96,000–144,000	125.28	83.52
16	144,000–192,000	475.20	316.80
17	192,000–240,000	518.40	345.60
18	240,000–720,000	1,036.80	691.20
19	720,000–1,200,000	2,112.00	1,296.00
20	1,200,000–1,680,000	2,208.00	1,440.00
21	More than 1,680,000	2,304.00	1,584.00
Rate on excess volume of water usage per month		Water usage up to 100 m ³ – no extra charge Water usage more than 100 m ³ – 0.072 per m ³ Water usage more than 200 m ³ – 0.11 per m ³	

Note: 'Commercial premises' means any building used wholly or partly for trade, business, provision of services or any other activity, whether for profit or otherwise.

While industrial premises will be charged based on the total number of employees, excess water charges apply in particular to governmental and commercial entities.

4.3 Specific Guidelines for Fecal Sludge Desludging Trucks and Accessories

Septage collection and transportation service providers, be they public or private entrepreneurs, need to comply with regulations to ensure that business operations satisfy safety regulations to maintain social, public and environmental health. Local governments can develop the operating structure for desludging services in two ways:

- Contract out local entities' own trucks for cleaning and emptying services to licensed contractors, who can work on scheduled septic tank emptying plans; or
- Encourage the contractors to invest in procuring emptying trucks as well as operating them, while local entities also provide access to their parking and cleaning stations (usually at WWTPs).

The core of the regulations in the transport section of the service chain targets compliance with technical and safety standards to minimize public and environmental health risks. Using the Philippine guidelines as an example (USAID 2008), every service vehicle needs to comply with the following requirements:

- Display the company name, company logo, contact number and business registration number of the FS hauler or transporting vehicle on both sides of the vehicle;
- Display the service area (municipalities or suburbs covered by their permits) and final desludging station;
- Have a leak-proof body (tank) and a strong locking mechanism that can withstand a collision with another vehicle or any permanent structure;
- Other specific requirements:
 - All piping, valves and connections should be accessible for cleaning.
 - All inlet and outlet connections should be constructed and maintained in such a manner that no material will leak, spill or run out of the tank during transfer or transportation.
 - Discharge outlets should be designed to control the flow of discharge (to avoid spraying or flooding of the receiving area).
 - Workers must wear appropriate personal protective equipment (PPE), including rubber gloves, rubber boots, a face mask and eye protection, must wash their hands with soap and bathe properly.
 - Last but not least, for monitoring compliance with regulations, the septage collection service providers must maintain a record-

keeping system about households served and land application, e.g., as described by the Minnesota Pollution Control Agency (2015).

4.4 Regulations on Fecal Sludge Emptying and Transportation: Examples from Selected Countries

Many low-income countries do not have any regulations on utility operators. In countries where such regulations exist, requirements are often based on existing standards from other countries, adapted to local implementation capacity and other applicable standards from the existing regulatory systems. Two major aspects of regulations are (a) occupational health and safety (OHS) standards and (b) the service standards. The following examples show what such guidelines can entail, from truck registration to health care:

Malaysia: Malaysian guidelines require FSM service providers to obtain various licenses, permits or levies from different authorities. These licenses are used as tools to monitor the industry. The relevant agencies responsible for handling different authorization procedures, while conforming to the requested standards in Malaysia (Ho et al. 2011), are listed below:

1. The National Water Service Commission – permit for desludging services.
2. Department of Occupational Safety and Health – permit for operation of pressure vessels.
3. Construction Industry Development Board – registration of operators.

In addition, these authorities should regularly inspect the activities and performance of permit holders and service licenses. Supervision of fair pricing is part of the regulation.

The Philippines: Only operators with a valid sanitary permit are authorized to collect and transport domestic sludge and FS. The driver and service providers are responsible for safe operation of the vehicle and equipment at all times. Drivers should inspect all trucks prior to transport on public roads to ensure that FS will not leak, spill or run out of the tank. After the desludging operation, the truck operator should clean and disinfect any spills with a bleach solution or by spreading lime on the spillage and must verify that sufficient disinfectant (bleach or lime) is on the truck before proceeding to a collection site. Preferably, collections should be performed when traffic is light in the area. The transfer of sludge from the original vehicle to another collection vehicle during transportation is normally prohibited. However, when such transfer is unavoidable, like in the case of transfer stations (Box 3), applicable transfer techniques, including loading and unloading, shall be included in the operational process and proposed to and verified by the relevant authorities to ensure health and environmental protection (Magtibay 2006; USAID 2008). The guidelines emphasize that all FS haulers/mobile service operators are required to

obtain an Environmental Sanitation Clearance certificate for which the following information needs to be provided:

- Proponent information and contact details;
- Scope of activities;
- Area covered;
- Method of collection;
- Type of vehicles and equipment;
- Occupational and health safety measures;
- Staffing plan; and
- Mitigating/control measures.

Moreover, FS haulers should provide documentation for each load of material collected, transported and delivered to a permitted facility or for land application.

Australia: The South Australian guidelines require the contractor to keep records to the satisfaction of the local council, including details of dates when OSS facilities have been desludged and the location of FS disposal. The contractors that transport FS for land spreading should obtain a license from the state Environmental Protection Agency (EPA). Transport of FS is not permitted, except by a person licensed by the EPA. Vehicles used to transport FS must only be cleaned in a location that provides the needed water treatment facilities and prevents washdown water from entering the stormwater system; preferably only at WWTPs, or at sites approved by the EPA for the reprocessing of FS. Any transport spills should be cleaned up rapidly. Dry clean-up methods are preferred in general. Flushing of overflow FS into waters is prohibited and will result in action being taken by the EPA (Brown et al. 2017). If a licensed contractor is not available to pump out a septic tank, permission for desludging by householders may be obtained from the local council.

Bangladesh: Recently developed guidelines for FSM have compiled legal obligations of local government bodies and roles as well as the responsibilities of each stakeholder involved in FSM. The guidelines suggest several measures be taken by local government bodies:

- Develop a database with the full address and family information of all emptiers (both manual and mechanized);
- Organize training sessions on safe emptying and transportation;
- Provide free PPE to emptiers;
- Establish a safety committee in each administrative district in line with the Bangladesh Labor Act 2006;
- Develop compensation mechanisms for victims of FSM-related occupational illness or injury in line with the Bangladesh Labor Act 2006;
- Implement mechanisms for monitoring the use of PPE and discharge of sludge in approved locations; and
- Ensure the availability of free health care services for emptiers and their family members at clinics/hospitals administered by the city corporation, or develop partnerships with NGO-run clinics to provide these services.

The guidelines also recommend a sequence of steps for the operation of vacuum trucks in order to accomplish sludge removal and protect the equipment and health of the service providers. Given the common practice of manual emptying in Bangladesh, the guidelines (Chowdhury et al. 2015) emphasize OHS measures, such as:

- Analyzing OHS risks during a pre-operation visit to the emptying site;

BOX 3. SEPTAGE TRANSFER STATIONS.

Large vacuum tankers often have difficulty in navigating areas with narrow streets. In such situations, small vacuum trucks can be deployed for the desludging of septic tanks or pits. However, their small capacities require multiple trips to the disposal site when emptying dense settlements, making transfer stations necessary. The same applies to larger trucks carrying sludge below capacity to remote disposal sites far out of town, or for optimizing availability to customers versus being stuck in traffic to dispose of the collected FS. Related to the financial advantage of transfer stations for septage transport operators, the stations also help to prevent illegal dumping of septage to save transport time and cost.

Septage transfer stations should be installed at strategic locations to serve as temporary holding facilities. There is a range of options depending on the local context (Mukheibir 2015). Key requirements are that the stations must be located at strategic locations that can safely receive septage from numerous small operators to enhance their operational feasibility and financial viability; but they must meet all human and environmental health regulations (minimum buffer zone, site restrictions, odor and vector control, protection gear usage, permits, safety regulations etc.) Also, these stations must be completely synchronized with long-haulage operators to ensure regular emptying and septage transportation to the approved final disposal or reuse site.

- Wearing appropriate clothing, including PPE;
- Examining the suitability of equipment to be used for emptying and transportation;
- Checking for the leaking points of pipes, if any;
- Ensuring sufficient lighting;
- Arranging provision of first aid kits;
- Arranging provision of water bottles;
- Avoiding drinking of alcohol;
- Ensuring the use of PPE during emptying and transportation;
- Locating the OSS the sludge is to be removed from;
- Determining the accessibility of the system once it is located;
- Being careful when opening tank covers or utility holes manually;
- Entering the tank should be avoided, but if necessary, allow time for the gases to flow out; ladders should be used when needed;
- Closing and securing the system once sludge removal has been completed; and
- Cleaning up appropriately on completion to ensure good personal hygiene; using soap during bathing.

India: Following the 2017 policy on FS and septage management in India, state-specific policies, strategies and guidelines conforming to the national policy are being developed. The Tamil Nadu guidelines, which address collection, provision for treatment and safe disposal of septage, seek to empower local bodies with knowledge, procedures and facilities for effective septage management. Accordingly, only certified and licensed septage operators can desludge and transport septage to the designated sewage treatment plant (STP) and these operators should be selected in accordance with the Tamil Nadu Transparency in Tenders Act, 1998. Furthermore, septage transportation vehicle operators should be well trained and equipped with protective safety gear, uniforms, tools and proper vacuum trucks to ensure safe handling of septage.

The guidelines encourage record-keeping and reporting through management information systems to maintain information related to septage generation, the type of OSS, the operator in charge of each location, the name and location of the STP earmarked for disposal of septage and so forth. A valuable initiative under these guidelines is the use of geographical information systems to plan the route of septage vehicles and track them for regular record-keeping (Government of Tamil Nadu 2017).

4.5 Other General Health Requirements for Operators

FS is hazardous and infectious material. It can cause disease if inhaled, ingested or put in contact with broken skin. Hands must always be washed immediately after coming into contact with FS and especially prior to eating and drinking. Tools and equipment that come into contact with FS need to be cleaned after use. FS workers should be immunized at least against tetanus, hepatitis A and hepatitis B, and dewormed (via pills). Smoking, drinking and eating must be prohibited while operating FS equipment because they promote the 'hand-to-mouth path' and hence increase infection risks.

Caution around septic tanks is essential and workers should never enter a septic tank without due precaution. These tanks are confined spaces that may contain toxic or oxygen-limited atmospheres and deaths from careless entry occur every year. Furthermore, accidents can result following damage to septic tanks if excessive weight is placed on the lid or utility hole cover (Robbins 2007). Although it is not recommended, manual cleaning is common in low-income country contexts. All relevant precautions should be practiced during manual desludging to protect the workers.

5. REGULATIONS AND GUIDELINES FOR FECAL SLUDGE TREATMENT AND DISPOSAL

5.1 Treatment and Disposal Overview

The treatment of FS helps to prevent possible risks to public health and the environment. To allow sustainable operations in low- and middle-income countries, septage treatment methods need to have low capital and O&M costs, low energy consumption and, if possible, the capacity to support operational cost recovery (Table 16). Adopted systems should be compatible with the expertise, climatic and local contexts of the particular country and with the institutional/entrepreneurial set-up responsible for scheme implementation and servicing (Eawag/SANDEC 1998).

TABLE 16. OVERVIEW OF COMMON APPROACHES TO FS TREATMENT.

Category	Description	Method	Advantages	Disadvantages
Co-treatment at STP	Septage is added to a treatment plant for co-treatment. Septage volumes that can be accommodated depend on the plant capacity and types of processes employed	Sludge can be added to different stages of the treatment process including upstream sewer utility holes, plant head works, liquid stream and sludge handling processes	<ul style="list-style-type: none"> • Most plants are capable of handling moderate quantities of septage • Synergizes waste treatment operations 	<ul style="list-style-type: none"> • Potential for plant dysfunction if input is not properly controlled • Increased residual handling and disposal requirements • As it is mixed with sewage sludge, likely unsafe for agricultural reuse
Treatment using own plant	<ul style="list-style-type: none"> • A facility is constructed solely for septage treatment • Treatments may generate residuals which need to be disposed of 	Stabilization lagoon, composting, anaerobic digestion, lime stabilization, chlorine oxidation	<ul style="list-style-type: none"> • Provides a tailor-made solution to septage management • Allows resource recovery for agriculture or energy 	Capital and O&M cost; additional compliance with regulatory requirements, compared to the option above
Land application (see Section 6)	<ul style="list-style-type: none"> • Septage is applied at secured sites away from the public • Stabilization to reduce odor, pathogens or vector attraction may be required, unless the FS has already been treated • Land application can be on surface soil or through injection into the soil 	Surface application, subsurface application	<ul style="list-style-type: none"> • Simple, economical • Recycles organic material and nutrients to the land • If safety guidelines are followed, can be used as nutrient input in agriculture • Low energy demand 	<ul style="list-style-type: none"> • Need for a holding facility during periods of frozen or saturated soil • Need for a relatively large land area, not visited by the public • Not possible where slopes are steep, and surface water or groundwater bodies can be affected

Source: USEPA (1994).

There are three common approaches: the addition of septage to an existing WWTP, the treatment of septage in a dedicated septage treatment plant, and land application. As land application also serves resource recovery and reuse (RRR) purposes, it will be addressed in Section 6.

In Minnesota, for example, the options for FS management are determined by where a household is located in the state. In the larger metropolitan areas, it is common for septage to be discharged into a publicly operated WWTP where it is treated. At that point, the septage becomes the treatment plant’s responsibility and is subject to the legislation for sewage sludge management and biosolid use. In smaller communities or areas that are not close to a treatment plant, transfers are not practical and septage is typically land applied. Septage disposal in landfills is not allowed in

Minnesota because it is in liquid form and waste landfills cannot accept materials containing free liquids (Minnesota Pollution Control Agency 2015).

5.2 Treatment of Fecal Sludge at Wastewater Treatment Plants (Co-treatment)

Where WWTPs are available, they can constitute a low-cost and environmentally sound option for septage treatment. However, if WWTPs are not designed to handle additional septage loads, the overload of biodegradable matter and nutrients can cause negative effects on facility performance and, ultimately, on effluent quality and operational cost.

A conventional activated sludge plant (with a primary clarifier) designed for 7,500 m³ day⁻¹ and operating at 50% capacity should be capable of receiving up to 100 m³ septage day⁻¹.

An extended aeration plant having the same capacity and operating at 50% capacity could receive 45 m³ septage day⁻¹ (USEPA 1994). However, as many WWTPs in developing countries might either operate below design capacity, as the supporting sewer systems are not yet in place, or far above capacity (e.g., at a 130% level) as infrastructure upgrading did not keep pace with the increase of sewer connections, regulations have to consider the facility performance limits, which depend on the manner and the part of the process in which septage is introduced. The impacts of adding septage to WWTPs include:

- Increased volume for screening and grit remains that require disposal;
- Increased odor emissions from head works;
- Scum accumulation in clarifiers;
- Increased organic loadings for biological and sludge handling processes;
- Potential odor and foaming problems in aerated basins;
- Increased sludge volumes requiring final disposal; and
- Increased housekeeping requirements.

Key points of a regulation on co-treatment of septage at WWTPs could be:

1. If a person is engaged in septage collection, that person shall dispose of the septage at a receiving facility within whose operating area the person is engaged in servicing, as approved by the regulator.
2. A receiving facility may charge a fee for receiving septage.
3. Authorities may issue an order prohibiting delivery of FS to the WWTP or the facility if the receiving facility has excessive hydraulic or organic loading, odor problems or other environmental or public health concerns.
4. A person shall not dispose of septage at a WWTP or facility if the operation of the WWTP or inlet structure as a receiving facility is prohibited by a public order.

Treatment of septage at WWTPs can use different entry points (Table 17).

TABLE 17. DIFFERENT OPTIONS FOR HANDLING FS AT WWTPS.

Method	Description	Advantages	Disadvantages
Septage addition to upstream sewer utility holes	Septage is added to designated sewers upstream of the WWTP	<ul style="list-style-type: none"> • Simple and economical due to the very simple receiving station design • May provide substantial dilution of septage prior to reaching the WWTP 	<ul style="list-style-type: none"> • Only feasible with large sewers and treatment plants • Odor potential near utility holes • May be difficult to control access • Potential for accumulation of grit and debris in the sewer
Septage addition to plant head works	Septage is added to sewage immediately upstream of screening and grit removal	<ul style="list-style-type: none"> • Simple and economical due to the very simple receiving station design • Allows WWTP staff to have control of the septage discharge 	<ul style="list-style-type: none"> • Interference with plant routine, adds to cost at head works • May affect WWTP processes if septage addition is uncontrolled or the treatment plant is too small • Increases odor potential at the treatment plant
Septage addition to the sludge handling process	Septage is handled as sludge and processed with WWTP sludge after pretreatment in the receiving station	<ul style="list-style-type: none"> • Reduces loading to liquid stream processes • Eliminates potential for affecting effluent quality 	<ul style="list-style-type: none"> • May have an adverse effect on sludge treatment processes such as dewatering • May cause clogging of pipes and increase wear on pumps if not screened in the receiving station • Expensive due to receiving station cost
Septage addition to both liquid stream and sludge handling processes	Septage is pretreated to separate liquid and solid fractions, which are then processed accordingly	<ul style="list-style-type: none"> • Provides more concentrated sludge for processing • Reduces organic loads for liquid stream and hydraulic loading for the sludge treatment process • Increases the flexibility of subsequent processing steps 	<ul style="list-style-type: none"> • Requires increased operations for septage pretreatment at the receiving station • Expensive due to additional receiving station costs

Source: USEPA (1994).

5.3 Treatment in Independent Fecal Sludge Treatment Plants

For situations where WWTPs are not available, too distant or have insufficient capacity, independent septage treatment facilities are needed. Such treatment plants may have separate units to handle both the liquid and solid portions of septage (USEPA 1994). There is emerging awareness of the potential benefits of introducing independent septage treatment systems that allow nutrient and organic matter

recovery from septage, while mixed systems with sewage sludge have a much higher contamination risk, e.g., from heavy metals.

Table 18 shows several treatment methods that can be employed alone and/or in combination. Criteria such as septage volume, quality, land availability, reuse options, possible odor as well as cultural aspects will determine which type of technology is best suited for a particular case.

TABLE 18. TYPES OF TREATMENT SYSTEMS FOR INDEPENDENT SEPTAGE TREATMENT PROCESSES.

Type of treatment	Description	Advantages	Disadvantages
Sedimentation/ stabilization ponds	Provides treatment through a combination of physical, biological and chemical processes combined with oxygen supply (aerators or atmospheric). The accumulated solids at the bottom undergo anaerobic digestion and are usually removed after several years	<ul style="list-style-type: none"> • Cost-effective with low technology and energy needs • Simple to operate • Reuse of effluent in irrigation possible • Can handle shock loadings • Synchronization with nature-based treatment solutions possible 	<ul style="list-style-type: none"> • Larger land area required • Requires professional maintenance • Less efficient in cold climates • Odor development • No heavy metal removal • Breeding ground for vectors
Co-composting (after dewatering)	High solid content septage is mixed with bulking agents (e.g., organic solid waste or sawdust) and aerated mechanically or by turning ‘in-vessels’ or large piles. High temperatures produced by bioactivity (above 50° C) for longer than one week) destroy pathogens	<ul style="list-style-type: none"> • The end product is a safe, marketable and beneficial soil amendment or organic fertilizer • Nutrient recycling for agriculture is supported 	<ul style="list-style-type: none"> • Dewatering is necessary prior to composting • Possible odor development • Operating costs are higher • Control of temperature, moisture and input requires skilled operators • Separate effluent treatment is needed
Anaerobic digestion	Fresh liquid FS, rich in biodegradable organic matter, is digested anaerobically, optimally together with animal dung, food or garden waste. Technology options can also include up-flow anaerobic sludge blanket reactors and biogas settlers	<ul style="list-style-type: none"> • The process generates energy • Stabilization of fresh sludge (pathogen destruction) • Limited land requirements • The digestate can be used as a soil conditioner 	<ul style="list-style-type: none"> • Depending on scale, relatively high investment cost • The biological process requires close control • Dilution of sludge with water may be needed • Other waste source needed for good digestion
Imhoff tank	<ul style="list-style-type: none"> • Normally only used for raw wastewater, but has also been tried for septage (Strande et al. 2014) • Allows settling of solids during digestion processes. Inclined walls make sure that rising gas bubbles produced by anaerobic digestion do not disturb the settling process • Digested sludge removed periodically by pumping or hydrostatic pressure and further treated 	<ul style="list-style-type: none"> • Settling and digestion in a single step • The land requirement is comparably low 	<ul style="list-style-type: none"> • The clarified supernatant generally requires further treatment • Expensive structure, risk of obstruction of the sludge draw-off pipe by thickened sludge when draw-off is not performed with adequate frequency

(Continued)

TABLE 18. TYPES OF TREATMENT SYSTEMS FOR INDEPENDENT SEPTAGE TREATMENT PROCESSES. (CONTINUED)

Type of treatment	Description	Advantages	Disadvantages
Settling/ thickening tanks	<ul style="list-style-type: none"> • Solids accumulate at the bottom and the clarified supernatant can be treated further. Accumulated sludge is removed periodically • Removed sludge generally requires further treatment • Can be used for partly stabilized FS, such as sludge from septic tanks 	<ul style="list-style-type: none"> • A simple and reliable process • The land requirement is comparably low 	<p>Not appropriate for very fresh sludge from public toilets, but may still be suitable if the fresh sludge is diluted with more stabilized sludge</p>
Unplanted drying beds	<ul style="list-style-type: none"> • Drying beds are gravel sand filters, equipped with a drainage system. Raw or presettled FS is loaded on the bed and contained water is evacuated mainly by percolation, but also by evaporation. Dewatered sludge is suitable for disposal • Further treatment for pathogen removal is necessary if the dried sludge is to be reused, e.g., through composting 	<ul style="list-style-type: none"> • The technology is well known and reliable • Low moisture content of dried solids and relatively good percolate quality • Relatively easy mechanical operation and maintenance 	<ul style="list-style-type: none"> • Percolate quality improves through filtration but may still require polishing treatment • Solids are not hygienically safe yet • Protection against rainfall needed • Larger land requirements
Reed bed filters/ constructed wetland	<p>The dewatering technique uses a lined cell of porous sand media with an underdrain system and planted wetland vegetation. Filtered liquid is further treated or disposed of via spray irrigation or subsurface wetlands. Solids are periodically removed from the reed bed for disposal</p>	<ul style="list-style-type: none"> • Low capital and energy costs • Low odor potential • High quality filtrate • O&M requirements comparably low 	<ul style="list-style-type: none"> • Solids must be periodically removed • Moderate land area requirement • Difficult to clear and to maintain • Risk of overloading
Alkaline stabilization (lime addition)	<p>Ash or CaOH₂ are added to septage in sufficient quantities to kill pathogens at a high pH (10–12) for an extended time, which also minimizes odor. Can be applied in septic trucks or in pits after land disposal</p>	<p>Low capital cost and simple technology. Can be combined with drying beds and also with (subsurface) land application of fresh FS</p>	<ul style="list-style-type: none"> • Pathogen regrowth is possible. Lime availability can be a challenge. Do not use CaCO₃ or CaO • Risk of hazard to eyes, skin and respiratory system possible. Do not use in septic tanks
Incineration (after drying)	<p>Sludge to heat (incineration) is a means of sludge minimization as 30% of the dry solids remain as ash. It can be cost-effective where it can be co-processed at coal-fired power plants, cement plants and in some solid waste incineration facilities</p>	<ul style="list-style-type: none"> • Production of electricity and heat • Substantial reduction of FS weight and volume • Complete destruction of all types of pathogens 	<ul style="list-style-type: none"> • Requires dried sludge. High investment, operation and maintenance cost • Risk of emissions which endanger human health and the environment

Unplanted drying beds are popular in low-income countries, given their low capital requirement and O&M cost, as long as there are sufficiently high temperatures, sunshine and drying area available. Table 19 presents the

estimated area required for drying beds for different FS strengths, showing that optimal drying conditions nearly halve the drying bed area required for each sludge load or FS strength.

TABLE 19. DRYING BED AREA (M²) FOR DIFFERENT FS STRENGTHS AND FEEDING RATES IN A TROPICAL CLIMATE.

		Low strength FS			High strength FS	
Total solids (g l ⁻¹)		5	12	22	35	50
Sludge load (m ³ day ⁻¹)		Drying bed area (m ²)				
Poor condition for drying	25	460	1,100	2,010	3,190	4,560
	50	910	2,190	4,020	6,390	9,130
	75	1,370	3,290	6,020	9,580	13,690
	100	1,830	4,380	8,030	12,780	18,250
	125	2,280	5,480	10,040	15,970	22,810
	150	2,740	6,570	12,050	19,160	27,380
Optimum condition for drying	25	230	550	1,000	1,600	2,280
	50	460	1,100	2,010	3,190	4,560
	75	680	1,640	3,010	4,790	6,840
	100	910	2,190	4,020	6,390	9,130
	125	1,140	2,740	5,020	7,980	11,410
	150	1,370	3,290	6,020	9,580	13,690

Source: IWMI, unpublished data.



Illegal FS dumping in Bangalore, India (photo by Sharada Prasad).

6. REGULATIONS AND GUIDELINES FOR FECAL SLUDGE USE

There are different options for FS use, particularly as a soil conditioner (land application in raw form or as compost or co-compost), building material (cement mixture), biofuel (gas, char briquettes) and in the production of protein (e.g., animal feed and via the black soldier fly) (Figure 4).

Apart from land application for FS disposal rules and guidelines for FS use in agriculture, regulations for other reuse options are rare. The following sections are limited to FS use in agriculture and aquaculture, with additional information on FS use as dry fuel at the household level and in the cement industry.

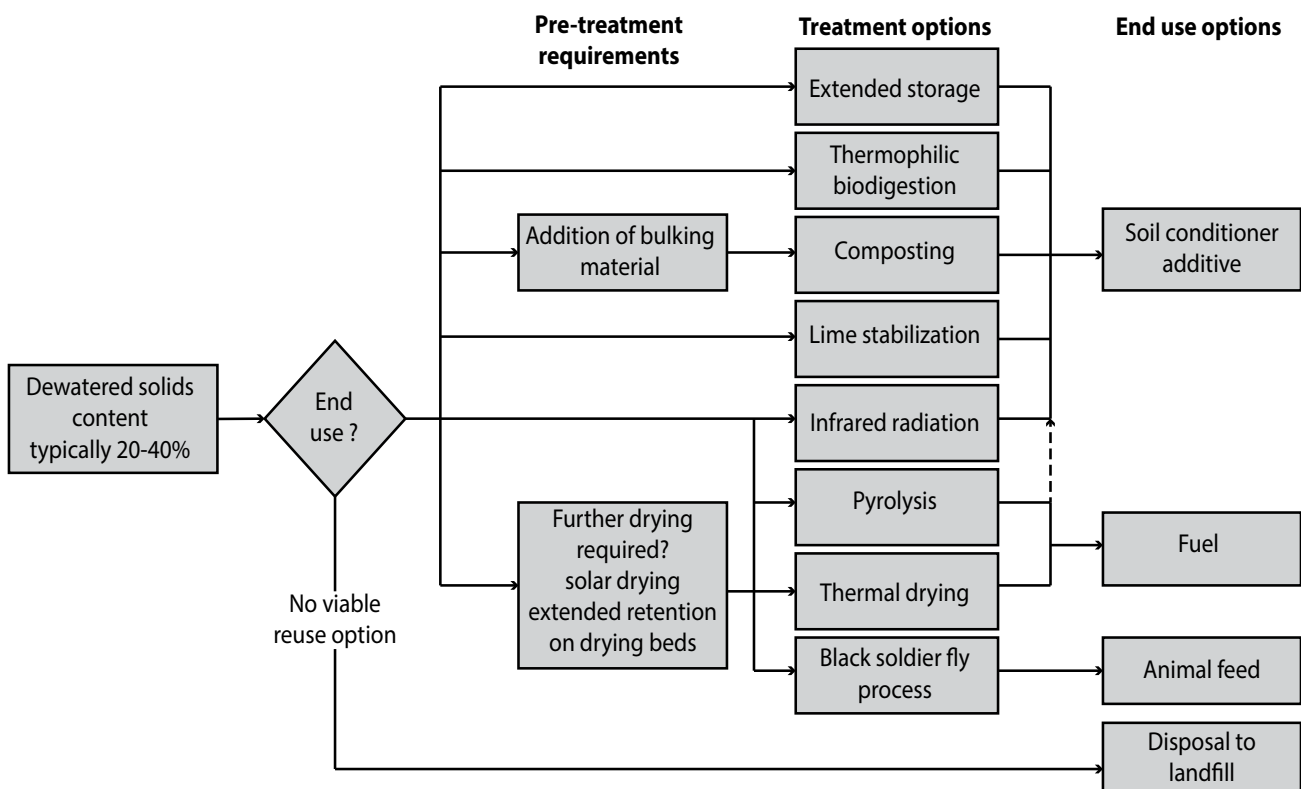
6.1 National Guidelines for Agricultural and Non-agricultural Land Application

Many types of 'land application' are possible, and they require different guidance depending on the sludge treatment level, and agricultural or non-agricultural use as well as

public exposure. A comprehensive regulation in this regard is the United States Environmental Protection Agency's (USEPA's) Standards for the Use or Disposal of Sewage Sludge (Title 40 of the Code of Federal Regulations [CFR], Part 503). This also considers **domestic septage** and sets separate (simplified) requirements for its application on nonpublic contact sites. These include agricultural land, forests or reclamation areas (USEPA 1993a). Domestic septage is defined in this context as a liquid or solid material removed from a septic tank, cesspool, portable toilet or similar system that receives only domestic (and not industrial) sewage. Part 503 uses the term biosolids instead of sewage sludge to describe primarily organic solid products produced by wastewater treatment processes that can be beneficially recycled, including material derived from biosolids, like co-composts or other sludge-waste mixtures.

Part 503 describes among others the ceiling concentrations (mg kg dry weight⁻¹, mg hectare⁻¹ and the load in kg ha⁻¹ and year⁻¹) for heavy metal contents in biosolids applied to land that cannot be exceeded, specifically, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium and zinc. If a limit for any one of the pollutants is exceeded, the biosolids cannot be applied to the land (Table 20).

FIGURE 4. OVERVIEW OF END-USE AND TREATMENT OPTIONS.



Source: Tayler (2018).

TABLE 20. POLLUTANT CEILING CONCENTRATIONS IN BIOSOLIDS.

Pollutant	Ceiling concentration (mg kg ⁻¹ dry weight)
Arsenic	75
Cadmium	85
Copper	4,300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7,500

Source: USEPA (1993a, 1993b).

Regarding pathogens, septage must be stabilized prior to disposal. Stabilization refers to treatment processes that reduce the pathogens to levels safe for land application. According to USEPA (1993b), one of the following recommended methods should be used to treat septage before agricultural land application (also see USAID 2008; WHO 2006b):

- **Aerobic digestion** for 40 days at 20° C or 60 days at 15° C.
- **Anaerobic digestion** for 15 days at 35 to 55° C or 60 days at 20° C.
- **Air drying** for at least three months. Two of the months must have average daily temperatures above freezing.
- **Composting or co-composting** at temperatures greater than 40° C for five days. The temperature of all of the material being composted must be greater than 55–65° C for at least four hours during the five days.
- **Lime stabilization** to bring the pH higher than 12 for 30 minutes, or bring the pH higher than 9 during more than six months if the temperature is above 35° C and/or moisture is below 25%.

The USEPA (1993b) guidelines also stipulate requirements on application methods for the use of untreated septage:

- 1) (Authorized) land appliers must assure that they have only domestic septage, will deposit it only at

sites that are not frequently visited by the public and will reduce the impacts from pathogens.

This includes reducing the FS' attractiveness to vectors (insects and rodents) for example through:

- a) **Injection:** FS must be injected into the soil. No significant amount of FS can be present on the soil surface within one hour after injecting, or
- b) **Immediate incorporation:** FS must be incorporated by tillage within six hours after surface application,
- c) An alternative option to the first two is **lime stabilization:** The pH of the FS must be raised to 12 or greater by alkali addition, and without the addition of more alkali, the pH must remain at 12 or higher for not less than 30 minutes.

The (authorized) owner of the land where domestic FS has been applied must adhere to safety protocols for crop harvesting, animal grazing and site access restrictions.

The number of gallons of domestic FS applied per acre may not be more than needed to supply the nitrogen required by the crop being grown. The maximum volume of domestic FS that may be applied to any site during a 365-day period depends on the amount of nitrogen required by the planned crop and aimed yield. This maximum volume is calculated by the formula:

$$AAR - \text{Annual Application Rate (gallons acre}^{-1} \text{ year}^{-1}) = \frac{\text{pounds nitrogen required for crop yield}}{0.0026}$$

Annual rate guidance is intended to prevent nitrogen application in excess of crop needs and limit its potential to be washed into soil and GW. An additional requirement is to limit the application to sites with a GW table deeper than 30 feet (North Dakota Department of Health 2015).

The AAR formula was derived using assumptions to make land application workable for domestic FS haulers. For example, fractional availability of nitrogen from land-applied domestic FS was assumed over a three-year period to obtain the ‘0.0026’ factor in the formula. Also, in deriving the formula, domestic FS was assumed to contain about 350 mg kg⁻¹ total nitrogen and 2.5% solids (about 1.4% total nitrogen on a dry weight basis).

Part 503 imposes separate requirements for domestic septage applied to agricultural land, forest or a reclamation site (i.e., nonpublic-contact sites). The ‘simplified rule’

for application of domestic septage to such sites is explained in the Domestic Septage Regulatory Guidance: A Guide to the EPA 503 Rule (USEPA 1993b). However, if domestic septage is applied to public contact sites or home lawns and gardens, the same requirements must be met as for bulk biosolids applied to the land (i.e., general requirements, pollutant limits, pathogen and vector attraction reduction requirements, management practices, frequency of monitoring requirements and record-keeping and reporting requirements). Table 21 summarizes selected related criteria as specified by USEPA regarding the minimum duration between the application of class B biosolids and harvesting of certain crops, animal grazing and public exposure/access. These minimum durations significantly reduce health hazards to levels equivalent to those achievable with the unregulated application of Class A biosolids. Additional lime application will modify the requirements.

TABLE 21. MINIMUM DURATION BETWEEN APPLICATION AND HARVEST/GRAZING/ACCESS.

Class B biosolids	Period between land application and harvest/grazing/access			
	Criteria	Surface	Incorporation	Injection
Food crops in which the harvested parts may touch the soil/biosolid mixture (beans, melons, squash, etc.)		14 months	14 months	14 months
Food crops in which the harvested parts grow in the soil (potatoes, carrots, etc.)		20/38 months ^a	38 months	38 months
Food, feed and fiber crops (field maize, hay, sweet corn, etc.)		30 days	30 days	30 days
Grazing animals		30 days	30 days	30 days
Public access restrictions				
- High potential for public exposure ^b		1 year	1 year	1 year
- Low potential for public exposure		30 days	30 days	30 days

Note: Class B biosolids applied to the land:

^a The 20-month duration between application and harvesting applies when biosolids that are surface applied stay on the surface for four months or longer, prior to incorporation into the soil. The 38-month duration is in effect when the biosolids remain on the surface for less than four months prior to incorporation.

^b This includes application to turf forms, which place turf on land with a high potential for public exposure. In general, stockpiling of Class B biosolids in the open field should be avoided, and if practiced, runoff to surface water or any adjacent land where community members may be exposed has to be avoided.

Source: USEPA (1993a, 1993b).

Suitable local climatic and soil conditions are required to avoid adverse impacts from land application through runoff of wastes and contaminants from application sites and preventing contamination of GW (Tables 22 to 24).

As amendments to the USEPA guidelines, many states such as Michigan, Minnesota, Pennsylvania, North Dakota and Ohio have formulated their own regulations and guidelines for septage disposal and reuse, specifically applicable to their local context. Some examples are:

1. Septage and Restaurant Grease Trap Waste Management Guidelines – Minnesota Pollution Control Agency (2015).
2. Natural Resources and Environmental Protection Act, Septage Waste Services – Legislative Council, State of Michigan (1994).
3. Handbook for the Collection, Transportation, Disposal, and Land Application of Residential Septage – Pennsylvania Department of Environmental Protection (2013).
4. North Dakota Septic Pumper Manual – North Dakota Department of Health (2015).

TABLE 22. SUITABLE SOIL CONDITIONS FOR LAND APPLICATION SITES.

Characteristic	Minimum requirement
Soil texture (US system)	At the zone of FS application (surface horizon or injection depth) the soil texture must be one of the following: fine sand, loamy sand, sandy loam, loam, silt, silty loam, sandy clay loam, clay loam, sandy clay, silty clay or clay
Surface horizon permeability	If 0.2 inches per hour or less, this soil is suitable only for surface application with incorporation within 48 hours or injection
Depth to bedrock	3 feet
Depth to seasonally saturated soil	3 feet
Frequency of flooding	Must not be occasional or frequent

Source: Minnesota Pollution Control Agency (2015).

TABLE 23. SLOPE RESTRICTIONS FOR APPLICATION SITES WHERE FS IS APPLIED TO LAND.

Slope (%)	Surface application	Injection or immediate incorporation
0-6	Allowed	Allowed
>6-12	Not allowed	Allowed
>12	Not allowed	Not allowed

Winter: Only areas with slopes from 0-2% can be used for winter applications of FS.

Source: Minnesota Pollution Control Agency (2015).

TABLE 24. DISTANCES (IN FEET) TO WELLS AND OTHER INFRASTRUCTURE.

Feature	Surface applied	Incorporated within 48 hrs	Injected
Private drinking water supply wells	200	200	200
Public drinking water supply wells	1,000	1,000	1,000
Irrigation wells	50	50	50
Residences	1,000	1,000	1,000
Public contact sites, including roads	200	200	50
Surface water features	200	200	200

Source: North Dakota Department of Health (2015).

Apart from the USA, other countries have developed guidelines for FS land applications to protect public and environmental health. Table 25 shows some key elements of selected guidelines. As septage reuse can be a controversial issue due to possible risks and different public risk perceptions, reuse regulations should be sensitive to perceptions and allow reviews and revisions as needed (see Chapter 7).

TABLE 25. GUIDELINES AND REGULATIONS FROM DIFFERENT COUNTRIES ON FS LAND APPLICATION.

Country	Land application method	Specific restrictions	Remarks
USA	Subsurface injection, spraying or spreading on the soil surface, or plowing, disking, injecting into the soil	<ul style="list-style-type: none"> If the FS is incorporated into the soil by plowing or subsurface injection, lime stabilization is not necessary If the FS is stabilized with lime it may be applied directly to the soil surface Restrictions are applied to the sites where crops are grown for human consumption 	The U.S. Code of Federal Regulations (40CFR) Part 503, compliance date February 19, 1995, gives more details on the treatment and disposal of FS

(Continued)

TABLE 25. GUIDELINES AND REGULATIONS FROM DIFFERENT COUNTRIES ON FS LAND APPLICATION. (CONTINUED)

Country	Land application method	Specific restrictions	Remarks
Alberta, Canada	It is common practice to apply sludge or biosolids to agricultural lands as a nutrient source rather than burning or landfilling it. However, this must be done in accordance with governmental standards and guidelines to avoid contamination of the receiving soils	<ul style="list-style-type: none"> • FS haulers need an authorization for land application with a schedule that includes details on individual sites where FS is applied • Application relates to stabilized septage only, and excludes (i) those (winter) months when ice, snow or frozen conditions exist; (ii) stream valleys and intermittent drainage areas; and (iii) land which does not meet predefined criteria in view of soil texture (not sand or gravel), pH (not if below 6.5), slope (not if above 5%) and aquifer depth (not if below 2 m) 	Several provinces in Canada allow septage use in agriculture. In Ontario, for example, the Ministry of Environment and Climate Change is currently reviewing its regulations on spreading of treated and untreated septage on land for crop nutrient supplementation (see chapter 7). The review has been initiated by public concerns in this context.
South Australia	Sludge from domestic septic tanks may be used in agriculture (excluding home gardens and horticulture for food production) without reference to the Department of Health or the EPA, provided that the guidelines are observed	<ul style="list-style-type: none"> • FS should be disposed over land so that (1) material does not pool or run off, (2) material does not create offense, disamenity and/or unsanitary conditions on or beyond the site • Spraying of aerosols should be reduced. There are rules for the frequency of application. The minimum distance between any FS application area and any open surface water course has to be at least 100 m. FS should not be applied within 400 m of any dwelling or adjacent properties or town boundaries 	<ul style="list-style-type: none"> • The stated EPA preference is for FS to be handled at a dedicated depot, if available, while the productive reuse of septage as well as treated biosolids from WWTPs is supported • For details see Box 4
The Philippines	Surface application	<p>All domestic sludge/FS shall be processed and treated before disposal to reduce risk. The following measures are recommended:</p> <ul style="list-style-type: none"> • Keep land application at a minimum of 10 m away from irrigation return flow ditches, rivers, streams, lakes or wells • The maximum FS rate is 264 m³ ha⁻¹ year⁻¹ • Spread the material evenly, on or just below the soil surface • Avoid applications on soils that are highly permeable, have low water holding capacity, shallow depth to bedrock or hardpan, high water table or slope steeper than 6% • Follow good irrigation water management practices to prevent surface runoff or leaching of nutrients 	<ul style="list-style-type: none"> • Only treatment plant operators or their authorized agents with valid Environmental Sanitation Clearances and Sanitary Permits are allowed to dispose treated septage or sludge on land • For agricultural land application, the Department of Agriculture will enforce the standards set in Box 5. In certain circumstances, land application is also possible for tree farms, landscape nurseries or land reclamation

BOX 4. LAND APPLICATION OF FS IN SOUTH AUSTRALIA.

Annex 6 of the South Australian guidelines for biosolids addresses the use of septic sludge (septage) independent of biosolids (which are defined as sludges that have been treated to a standard suitable for beneficial reuse).

The spreading of FS from domestic septic tanks to agricultural land has long been practiced in South Australian areas where purpose-built drying and storage facilities are not available. Although the EPA's preference is for FS to be handled at a dedicated depot, the advantages of reuse, e.g., in landscaping, forestry and agriculture have been recognized. Agricultural land includes in this context land used for pasture, cereals, tree crops and viticulture (grapes). Spreading FS on land used for intensive horticulture for food production is not permitted under these guidelines, and contact with grazing livestock is not allowed.

Application criteria

Transporters should be aware of prevailing wind directions and rainfall events before spreading FS onto land. FS should be spread onto land only in a manner that will allow for sustainable productive land use, and FS should be disposed over land so that (1) material does not pool or run off, (2) material does not create offense, disamenity and/or unsanitary conditions on or beyond the site.

Recommendations:

- Sludge needs to be screened so that intractable wastes (i.e., plastic, rags) are removed;
- The waste transport vehicle is kept moving; and
- The outlet from the vehicle is designed to reduce spray and aerosols and to spread the effluent evenly and thinly over the land. A flared application is preferred.

To achieve a recommended application rate of 100 kg N ha⁻¹ year⁻¹, FS has to be spread or applied evenly and thinly from one 8-m³ tanker over a minimum of 600 m² (based on the assumption that septage from a septic tank contains on average about 700 mg total Kjeldahl N l⁻¹). For example, a 1-ha plot can receive 16 units of 8-m³ tankers per year. Where a site is used for FS spreading, each event should be recorded so that repeated applications on the same land are avoided. Other requirements are:

- FS should not be applied continuously to the same area. Liquid waste transporters should identify and use several suitable sites for disposal in any one year. Sites should be rested for the period of the year during which FS is applied.
- Repeated application of FS onto the same land may breach the Environmental Protection Act. FS contains a higher percentage of nitrogen than biosolids, and sites that regularly receive FS should be monitored for soil health, nutrient levels and other possible environmental harm.
- Where possible, incorporate any application of FS into the soil on the same day and at most, within seven days. Apply FS at rates that allow it to dry rapidly, preventing odor generation and minimizing vector attraction. If crops are to be grown, establish them soon after the application to minimize leaching of nutrients into the GW.
- Because of infection risk to livestock, FS should not be spread on land used for grazing. Once the FS has been incorporated into the soil and the pastures have been re-established, livestock should no longer be at risk.

Land suitability

- Apply FS only onto well-drained lands with no steep slopes.
- Do not apply FS onto land if it could adversely impact ground- or surface water. Ensure a minimum distance of least 100 m between any FS application area and any open surface watercourse.
- Do not apply FS onto rocky or waterlogged ground.

Buffer zones

FS should not be applied within 400 m of any dwelling, adjacent properties or town boundaries. Weather conditions at the time of application should be considered to prevent odor transmission to any residence.

Source: Brown et al. (2017).

BOX 5. STANDARDS FOR AGRICULTURAL LAND APPLICATION OF TREATED SEPTAGE AND SLUDGE IN THE PHILIPPINES.

The Philippines encourages composting of septage for reuse as a soil amendment or use in landscaping, agriculture and horticulture. The proposed specifications are summarized in Tables 26 to 28.

TABLE 26. SPECIFICATIONS FOR FERTILIZERS AND COMPOST/SOIL CONDITIONER.

	Plain organic fertilizer	Compost and soil conditioner	Fortified organic fertilizer
Total NPK	5–7%	3–4%	8% minimum
C:N	12:1	12:1	12:1
Moisture content	<35%	<35%	<35%
Organic matter	>20%	>20%	>20%

The following standards have been specified by the Philippines for agricultural use or use involving human contact (e.g., at parks or playgrounds), which require detailed laboratory analysis to confirm that concentrations of pathogens and heavy metals are within safe limits. This is also applicable to septage-derived compost.

TABLE 27. TEST FOR PATHOGENS FOR ORGANIC FERTILIZER/SOIL CONDITIONER.

Pathogen	Safe limit
Fecal streptococci	$<5 \times 10^3 \text{ g}^{-1}$ compost
Total coliforms	$<5 \times 10^2 \text{ g}^{-1}$ compost
Salmonella	0
Infective parasitic	0

TABLE 28. ALLOWABLE LEVELS OF HEAVY METALS IN ORGANIC FERTILIZER/COMPOST SOIL CONDITIONER.

Heavy metal	mg kg ⁻¹ dry weight
Zn	1,000
Pb	750
Cu	300
Cr	150
Ni	50
Hg	5
Cd	5

Source: USAID (2008).

Lime stabilization for agricultural reuse

As mentioned above, lime application is an effective measure to stabilize sludge for disposal or reuse as well as a possible temporary measure for local governments that are planning for permanent septage facilities. Following the USEPA recommendations, in the Philippines a dosage of about 10–20 kg of hydrated lime (CaOH₂) is considered enough to process 4,000 l of septage to form a safe product that can be disposed of on land for use as a fertilizer. Once the lime and septage are mixed, the pH is raised to 12 and held for a minimum of 30 minutes. This kills any pathogens present

and ‘stabilizes’ the septage, thus reducing odors. The material can then be more easily handled for final disposal.

There are two common ways to perform lime stabilization:

1. Adding the lime directly to the (stainless steel) vacuum truck. Lime can be added either before or after the septage is pumped, but never directly in the toilet or septic tank. The pump in the truck can then be used to mix the lime and septage.
2. Adding the lime into a pit on the land that receives the sludge load daily or weekly. For details on pit design and loading rates, see USAID (2015).

Occupational risks on farms

Occupational risks of all who are in contact with FS along the service chain have to be addressed through protective clothing and hygiene. To minimize the risk to farmers who might work in some countries with unstabilized septage after and during application, Seidu (2010) recommends the following additional drying periods for the temperature conditions in northern Ghana:

- For septage spread on the soil surface, a drying time of at least 30 days (ideally 60 days) is needed to meet the WHO microbial monitoring benchmark for *E. coli* and helminth eggs (based on less than one *Ascaris* egg per gram of total solids). The same drying time results in rotavirus levels below the WHO tolerable infection risk level through accidental ingestion of small amounts of 'cake' sludge or sludge-contaminated soil.
- For buried septage, not exposed to the sun, three months of drying will allow meeting of the WHO microbial monitoring benchmark for *E. coli*, *Ascaris* and rotavirus infections.

6.2 International Guidelines on Fecal Sludge Reuse in Agriculture

There are international guidelines to safeguard public health, for example in the European Community, on the application of sewage sludge in agriculture (Directive 86/278/EEC), which set limits on the concentrations allowed in soils and

sludge of a range of heavy metals that may be toxic to plants and humans. Sewage sludge, in the context of this directive includes residual sludge from domestic or urban WWTPs as well as septic tanks. Most European Union (EU) member states have transposed the specifications of the directive into their national legislation on sludge. However, the sludge regulations in Belgium, Denmark, Italy and the Netherlands apply to use in agriculture of both urban sewage sludge and industrial sludge. The scope of national regulations on sludge is in most cases very similar to the definitions provided in the directive. Thus, very few specific provisions for sludge from septic tanks are included in national regulations. Septic sludge is mentioned, e.g., in the British and Irish sludge regulations, and in the Belgian Walloon region.

The Sewage Sludge Directive 86/278/EEC seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and humans. To this end, it prohibits the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. Treated sludge is defined as having undergone "biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use." WHO (2006b) provides an example of storage and treatment options (Table 29).

TABLE 29. RECOMMENDATIONS FOR STORAGE TREATMENT OF DRY EXCRETA AND FS BEFORE USE AT HOUSEHOLD AND MUNICIPAL LEVELS.

Treatment	Criteria	Comment
Storage; ambient temperature of 2–20°C	1.5–2 years	This will eliminate bacterial pathogens; regrowth of <i>E. coli</i> and <i>Salmonella</i> may need to be considered if rewetted; will reduce viruses and parasite protozoa below risk levels. Some soil-borne ova may persist in low numbers
Storage; ambient temperature > 20–35°C	>1 year	Substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosoma eggs (<1 month); inactivation of nematode (roundworm) eggs, e.g., hookworm (<i>Ancylostoma necator</i>) and whipworm (<i>Trichuris</i>), while a +/- complete inactivation of <i>Ascaris</i> eggs will occur within one year
Alkaline treatment	pH >9 over 6 months	If temperature >35°C and moisture <25%; lower pH and/or wetter material will prolong the time for absolute elimination

Source: WHO (2006b).

To provide protection against potential health risks from residual pathogens, the EU directive says that sludge must not be applied to soil in which fruit and vegetable crops are growing or grown, or be applied less than 10 months before fruit and vegetable crops are to be harvested. Grazing animals must not be allowed access

to grassland or forage land less than three weeks after the application of sludge. The directive also requires that sludge use should take into account the nutrient requirements of plants as well as the quality of the soil and ensure that the surface and groundwater is not impaired. As it is impracticable to monitor treated sludge for the

presence of (real) pathogens, surrogates should be used for routine evaluation of treatment plant performance and sludge quality. Surrogates should be organisms commonly found in sludges that have similar resistance to treatment as pathogens. *E. coli* (or enterococci) and *Clostridium perfringens* are suggested. Numbers of *E. coli* should not exceed 1,000 g⁻¹ (dry weight) and it is

tentatively recommended that spores of *C. perfringens* should not exceed 3,000 g⁻¹ (dry weight).

The constraints on the land application of sludge will vary according to the treatment to which the sludge has been subjected and the crops which are produced subsequent to the sludge application (Table 30).

TABLE 30. SUGGESTED LAND-USE CONSTRAINTS AFTER TREATED SLUDGE APPLICATION.

Crop	Advanced treatment	Conventional treatment
Pasture	Yes	Injection and three-week no-grazing period
Forage	Yes	Three-week no-harvest period
Arable	Yes	Injection or plow-in
Vegetables in contact	Yes	10-month no-harvest period
Fruit & vegetables eaten raw (salads)	Yes	30-month no-harvest period
Fruit trees, vineyards	Yes	Injection and 10-month no-access period
Parks & urban open spaces	Well-stabilized and odorless	No
Land reclamation	Yes	10-month no-access period

Source: Carrington (2001).

In terms of obligations for treatment, France, Ireland, Luxembourg and Sweden permit the use of untreated sludge under certain conditions (like direct injection), while Denmark, Finland, Germany, Italy, the Netherlands and Spain have prohibited the use of untreated sludge. In other countries, there is no specific legal requirement in this context. A review of relevant legislation reveals that very few elements in national regulations within the EU specifically address the use of sludge in routes other than recycling in agriculture (e.g., use in silviculture, in natural forest, green areas and in land reclamation). However, use of sludge on forest soil is mentioned by the regulation on sludge use in Belgium-Flanders, Denmark, France and Luxembourg. In addition, some national regulations have prohibited the use of sludge on silviculture (Germany, the Netherlands), on

natural forest (Germany), and in green areas (Germany, the Netherlands). Significantly, the regulation in Poland includes limit values for heavy metal concentrations in sludge for use in land reclamation and on “non-agricultural soil”. Like in national guidelines, it is generally recommended that the analysis of heavy metals becomes an integral component of any program that promotes the reuse of the treated FS as a soil amendment, especially where regular applications over longer periods could lead to metal accumulation in the soil. Table 31 shows the heavy metal thresholds as proposed for waste-derived compost by the EU Joint Research Centre’s Institute for Prospective Technological Studies, based in national standards across the EU. The data are more stringent than those presented e.g. in table 28 from the Philippines.

TABLE 31. PROPOSED HEAVY METAL THRESHOLDS FOR WASTE-DERIVED COMPOST BY THE EU JOINT RESEARCH CENTRE.

Heavy metal (per kg dry weight)	Symbol	Upper threshold
Lead (mg kg ⁻¹)	Pb	120
Chromium (mg kg ⁻¹)	Cr	100
Cadmium (mg kg ⁻¹)	Cd	1.5
Mercury (mg kg ⁻¹)	Hg	1.0
Nickel (mg kg ⁻¹)	Ni	50

Source: Saveyn and Eder (2014).

Hogg et al. (2002) indicated that the compost must be matured before any analysis is done, because the heavy metal concentration increases relatively during the composting process due to the loss of organic matter. Therefore, many regulatory schemes (for instance in the German Biowaste Ordinance) provide for the assessment of heavy metals to be standardized

at a specific level of organic matter (30% in Germany), whereas ‘fresh’ materials often show 60 to 70% organic matter.

In view of pathogens, most guidelines refer to WHO (2006b; Table 32) to support national authorities in the development of their own regulations for agricultural reuse.

TABLE 32. GUIDELINE VALUE FOR VERIFICATION MONITORING IN EXCRETA AND FS USE IN AGRICULTURE.

	Helminth eggs (number)	E. coli (number)
Treatment of feces and FS	<1 per g total solids	<1,000 per g total solids

Source: WHO (2006b).

Organic pollutants and micro-plastics

In recent years, a new set of pollutants has received international attention, i.e., those derived from pharmaceutical or health care products as well as micro-plastics. Regulations related to wastewater (sewage) treatment are adjusting to the emerging knowledge (Box 6), while regulations on FSM or FS-derived soil inputs will take longer. Reasons include (i) the lack of standard sampling and laboratory methods for FS and contaminants like micro-plastics, (ii) missing specialized laboratories able to analyze organic components in many countries, and (iii) missing dose-response functions to establish thresholds.

laboratory analysis of FS is however in print (Velkushanova et al. forthcoming).

The analysis of FS-derived compost, on the other hand, can follow conventional methods for the analysis of compost or organic matter. The proposed EU guidelines recommend that for end-of-waste criteria, it should be considered to include in future also testing requirements and limit values for certain organic pollutants, especially for polyaromatic hydrocarbon (PAH) which gets released from burning coal, oil, gasoline, trash, tobacco and wood, and perfluorinated compound (PFC) which derives e.g. from Teflon or water resistant textiles. These values thresholds will not be zero, as no technology or input material type provides a full safeguard against the presence of most organic pollutants (Saveyn and Eder 2014):

Until now, methods from other fields such as water, wastewater and soil science are commonly applied for FS, although these methods might not necessarily be the most suitable for FS. A dedicated reference guide for the

BOX 6. DEVELOPING NEW GUIDELINES FOR THE DESTRUCTION OF ENDOCRINE DISRUPTORS.

Endocrine disruptors are chemicals in FS and wastewater that affect some natural hormones, with potential negative effects on human, fish and wildlife health. Secondary wastewater treatment can remove some endocrine disruptors, but not all. Guidelines and regulations are emerging; early actors are the following:

- **Canada:** New regulations in force since 2015 require WWTP upgrade to ensure there is no acute toxicity, with a deadline expiry date of December 31, 2040 to meet effluent quality standards for carbonaceous-biochemical oxygen demand and suspended solids.
- **USA:** Based on relevant scientific evidence from a Colorado, Boulder WWTP, the USEPA upgraded estrogenic regulations.
- **EU:** Plant Protection Product Regulation, the Biocidal Product Regulation (REACH) and the Cosmetics and the Water Framework Directive provide specific details of how endocrine disruptors are banned or regulated to address health and environmental effects. In July 2017, the European Communities amended the regulations to include new endocrine disruptors.

Source: Krantzberg and Hartley (2018).

While national guidelines for compost production and use are common (e.g., Hogg et al. 2002; USCC 2018) and can include FS as one feedstock, guidelines for the soil application of biochar (based on FS or not) are only slowly emerging. However, driven by the ‘regulatory gap’, voluntary biochar quality standards have been formed, for example in Europe with the European Biochar Certificate, in the UK with the Biochar Quality Mandate and in the USA with the International Biochar Initiative, which could be used internationally. In parallel, biochar producers and biochar users in a number of EU countries have been partly successful in fitting biochar into the existing national legislation for fertilizers, soil improvers and composts (Meyer et al. 2017). A similar emerging status applies to urine. Regulations on urine reuse in agriculture could draw on Richert et al. (2010) and WHO (2016, Annex 1), for example.

6.3 Soil Application of (Co-)Composted Fecal Sludge

Commercialization as a crop fertilizer needs approval by the institution responsible for accreditation of fertilizer products. The application process might require field trials carried out by independent local institutions, which will need time and should not be underestimated (World Bank 2017).

FS is usually **co-composted** with other organic waste, like food waste, other organic MSW, sawdust and so forth. The mix of materials improves the carbon–nitrogen balance of the material, which again supports the microbial activities during the composting process. The better the composting is performing, the higher the temperatures in the compost pile and the elimination of pathogens (Cofie et al. 2016).

The resulting FS-based co-compost is a hybrid between (a) an organic soil ameliorant, which helps to improve soil physical characteristics, like soil structure/aeration, water and nutrient holding capacity, and (b) an organic fertilizer, which provides plants with crop nutrients. Although the ‘fertilizer’ role can gain in significance with increasing ‘fortification’ (enrichment with mineral fertilizer), the main role of the compost will remain the long-term improvement of soil organic matter and structure, and it would be wrong to expect any short-term impact comparable to a similar amount of a chemical fertilizer, which only consists of plant nutrients.

Compost application guidelines (Nikiema et al. forthcoming):

- FS-based composts may be used in different ways, either as a growing media, alone or combined with soil or biochar, or as a soil conditioner-*cum*-fertilizer (hybrid), to boost *and* sustain crop yields.
- Only matured (well-composted) FS products should be applied to soils in order to eliminate possible negative side effects (‘burning’) on crop growth.

- Application rates for FS-based composts vary with soils, crops and compost enrichment and range commonly between 5 and 25 t/ha.
- Compost or compost pellets can be applied in different ways (broadcasting, placement, etc.). If applied directly to a plant, the pellets should be placed about 5 cm (radius) from the base of the plant, not closer, either on the soil surface or buried at a depth of about 5 cm.
- Non-pelletized compost can be mixed with the soil or planting media. It can be applied on the soil surface or plowed into the soil, e.g., one week before planting.
- The quantity of a fertilizer to apply is in general defined by crop requirements and soil fertility. Nutrient requirements for specific crops can usually be obtained from the Ministry of Agriculture. Although crops need a range of different nutrients, it is common practice to calculate the fertilizer application rates based (only) on the crop nitrogen (N) demand. The same approach is commonly used for organic fertilizers despite their different strengths and benefits, which should be kept in mind in comparative field trials in view of short- and long-term costs and benefits.
- On very poor (sandy) soils, a compost can have a high impact by alleviating many soil structure- and soil fertility-related shortcomings, but it can only contribute to some extent to immediate crop nutrient requirements.
- Table 33 provides guidelines on application rates for a normal and an N-enriched (fortified) FS-based compost, based on crop nutrient needs and recommendations published in Ghana by the Ministry of Food and Agriculture. **These guidelines have to be adapted to local soil conditions and crops in different geographical domains, but can be used as a starting point for field trials.**
- As noted in Table 33, an N-enriched compost will for some crops still require an extra application of other nutrients, like phosphorus (P) or potassium (K). This might, for example, be the case on sandy or highly weathered soils and can be addressed through the use of additional fertilizer.

6.4 Fecal Sludge Reuse for Energy Production

Septage as fuel for household energy needs: Apart from land application, the transformation of FS into dry fuel or biogas is increasingly common. Pyrolysis is the thermochemical process of transforming biomass in the absence of oxygen into solid (char), gas and liquid products (liquids can be recovered from the condensable fraction of gas). Slow pyrolysis has been traditionally used to produce cooking charcoal using a heating temperature of 300 to 700° C (Cunningham et al. 2016). Fecal chars made at low temperatures can be briquetted, e.g., with molasses/lime and starch binders, resulting in heating values of around 25 megajoule kg⁻¹, which are comparable to those of commercial charcoal briquettes, making fecal char briquettes a potential substitute (Ward et al. 2014).

TABLE 33: RECOMMENDED FS COMPOST APPLICATION RATES IN GHANA FOR REGIONAL FINE-TUNING.

Crop	Quantity required of an enriched (3% N) FS-based co-compost (t/ha)	Quantity required of a not enriched FS-based co-compost (t/ha)	Possible additional P and K fertilizer needs depending on soil fertility
Cabbage	3.4	10.8	
Maize	3.0–4.0	10.0	
Okra	2.5	5.7	
Carrot	2.5		P
Watermelon	2.0		P, K
Tomato	3.2	8	K
Onion	2.5		
Garden egg	3.7	7.5–9.5	K
Cucumber	2.0		
Lettuce	4.3–5.0	12.5	
Banana	3.7		
Rice	3.2	7–8	

Source: Nikiema et al. forthcoming

While the produced biochar could be used for soil amelioration (see above), char production via pyrolysis and burning at home contribute to air pollution, which is connected to air quality regulations. To date, no official emissions' limits or guiding documents exist at the national or international level for fecal or wastewater sludge pyrolysis reactors. Cunningham et al. (2016) referred in their review of pyrolysis of FS air pollution regulations to the State of Massachusetts Department of Environmental Protection as well as air pollution emission requirements for US wastewater sludge incineration facilities. The Massachusetts-issued interim regulations for farm-scale pyrolysis reactors are based on the emissions' factors measured for industrial charcoal production from wood as a first approximation to identify pollutants that could occur during FS pyrolysis.

Incineration of biosolids is another process that can be used as a reference for FS pyrolysis. According to the USEPA, the major pollutants emitted during wastewater sludge incineration are particulate matter, metals, carbon monoxide, nitrogen oxide, sulfur dioxide and non-combusted hydrocarbons. The USEPA emissions' factors thus provide guidance on which pollutants would be expected from a pyrolysis process. However, the emissions' factors for wood charcoal production may have very different values to values measured as part of FS pyrolysis, which requires further research (Cunningham et al. 2016).

Septage as dry fuel for cement kilns: The use of alternative fuel sources, including sewage sludge, is common in the cement industry (WBCSD 2014). As septage use is less common, compared to sewage sludge use, in most developed countries, there are few specific regulations for its use, although it has been tested at scale (Wald 2017). However, it is possible to draw on existing regulations that

have been developed for co-processing MSW and sewage sludge in the cement industry. Regulations and standards are needed in five key areas (Hasanbeigi et al. 2012): (1) environmental performance, (2) product quality, (3) waste quality, (4) operational practices and (5) safety and health requirements for employees and local residents. As such, guiding points are (Hasanbeigi et al. 2012) listed below:

- (1) The high temperatures in rotary kilns ensure that organic substances in wastes are almost entirely converted to CO₂ and water and that the emission concentrations of harmful organic compounds, which can occur in sewage sludge, but less in septage, such as dioxins and furans, are very low. Nonetheless, air emissions, water discharges and residues from co-processing plants must be carefully regulated. Many countries around the world have established emission limits for different types of pollutants from co-processing plants.
- (2) Product quality requirements are intended to ensure that the use of waste-derived fuels in the cement industry does not result in a negative impact on human health or the environment, nor degrade the cement or brick composition or the technical properties that are essential to their functions as building material. Studies have identified three general principles that should be followed in developing regulations governing the quality of cement products (GTZ and Holcim 2006):
 - The product (clinker, cement, concrete) must not be abused as a sink for heavy metals.
 - The product should not have any negative impact on the environment.
 - The quality of cement should allow end-of-life recovery.

- (3) Plant operators should, in particular, check for the following contents within wastes because these constituents significantly affect the quality of production (WBCSD 2014; GTZ and Holcim 2006):
 - Phosphates, which influence the cement setting time.
 - Chlorine, sulfur and alkali, which affect overall product quality:
 - Chlorine concentrations greater than 0.7% can affect clinker strength;
 - Chlorine can cause accelerated corrosion of the facility; and
 - Chlorine affects the overall quality of cement and concrete.
 - Chromium, which may cause allergic reactions in sensitive users.
- (4) The EU Waste Incineration Directive requires that co-processing plants keep the co-processing gases “at a temperature of at least 850° C for at least two seconds.” The waste heat from the co-processing process must also be utilized “as far as possible.” The burning process should be monitored continuously by process control technology. Wastes containing volatile organic compounds (VOCs) must be stored and handled to allow suppression or containment of these components, such as in closed tanks or containers with appropriate air ventilation. Common techniques for capturing VOC emissions include nitrogen traps, biological treatment, activated carbon filters and thermal treatment (GTZ and Holcim 2006).
- (5) Operations and management staff should receive enough resources and training to ensure that a co-processing system runs safely and efficiently. Preventative measures, such as operational and control monitoring, personal protective equipment

and storage facilities must be employed to minimize potential risk to employees and local residents. Operation, maintenance and safety procedures should be developed for both employees and plants and should be reviewed, updated or modified regularly to ensure that they are fully implemented and meet the needs of changing operation conditions. Robust emergency procedures should also be developed.

6.5 Fecal Sludge Reuse in Aquaculture

Waste-fed aquaculture is centuries old in various countries in East, South and Southeast Asia, especially China. It has been developed mainly by farmers and local communities to use nutrients contained in wastes to produce aquatic food. There is a great diversity in current waste-fed aquaculture practices involving septage, fish and aquatic plants, including high-protein plants grown in wastewater as feed for fish grown in freshwater systems (e.g., duckweed) (Ahsan 2015). Wastewater may also be used in aquaculture nurseries to produce seed or fingerlings, which are then grown out to full-size table fish in separate systems without the use of wastes.

The practice is largely a grey area untouched by regulations and policies, although most waste-fed aquaculture involves the direct addition of waste with little or no prior treatment, resulting in a range of potential hazards: excreta-related pathogens (bacteria, helminths, protozoans and viruses), skin irritants, vectors that transmit pathogens and toxic chemicals. However, only a few risks are considered high. Microbial contaminants, for example, rarely penetrate into edible fish flesh or muscle except for trematodes (parasitic tissue flukes). In fact, the transmission of trematode parasites is of particular concern in aquaculture as trematode-associated diseases are associated with high morbidity. The risk can be reduced through FS storage prior to application (Table 34).

TABLE 34. TREMATODE RISK REDUCTION FOR EXCRETA USE IN AQUACULTURE.

Option	Effectiveness	Guidelines
Excreta storage prior to pond addition	Medium to high effectiveness for pathogen reduction	<ul style="list-style-type: none"> • Effectiveness depends on time; • Storage time starts only after last addition of FS; • Storage; and • Storage for 4 weeks reduces risks for most trematodes substantially, while 10 weeks are needed for <i>Fasciola</i> spp.

Source: WHO (2006a).

There are two types of trematodes of relevance in waste-fed aquaculture: food-borne trematodes (intestinal, liver and lung flukes) and schistosomes with infection by larvae penetrating the skin of people entering water

for domestic, occupational or recreational purposes. Protection is achieved by a combination of different measures, including cooking fish thoroughly prior to consumption.

Microbial quality targets for pond water have been established that can be used to facilitate compliance with WHO's health-based targets, e.g., (i) viable trematode eggs not detectable (per 100 ml or per gram of total solids); (ii) $\leq 10^4$ *E. coli* (arithmetic mean per 100 ml or per g of total solids) and (iii) ≤ 1 helminth eggs (per liter or per g total solids) to protect consumers (WHO 2006a). Finally, annex 1 of WHO (2006) presents design criteria for wastewater treatment ponds that can support microbially safe fish farming and could be referenced in national FS reuse regulations.

7. PUBLIC CONSULTATIONS AND POLICY REVIEW

Policy development and/or revision require early stakeholder involvement and buy-in. This can be of particular importance where potentially controversial subjects, such as wastewater or sludge reuse, are part of the agenda. For example, in Ontario the use of untreated septage resulted in public concerns about existing policies and regulations. That a policy can respond to such concerns through a formal **policy review process** supports public trust in the administration and should be built in the design of any policy and regulation.

To give an example, in 2017, the Ontario Ministry of the Environment and Climate Change (MOECC) in Canada started a review of its Hauled Sewage Policy and Program by seeking comments from the public and other stakeholders. Hauled sewage (septage), in the Ontario definition, is the waste material removed from portable

toilets, sewage holding tanks and septic systems. The MOECC regulates the transportation and land application or disposal of untreated hauled sewage through Environmental Compliance Approvals issued under the Environmental Protection Act, and through Ontario's General Waste Management Regulation (R.R.O. 1990, Reg. 347) under this act. If the hauled sewage is **treated** to an appropriate level, its application to agricultural land for crop benefit falls under the Nutrient Management Act to be exempt from the approval requirements for land application/disposal under the Environmental Protection Act.

In 2002, as a result of growing public concerns about the potential impact of the land application of **untreated** hauled sewage on the quality of groundwater and surface waters, Ontario proposed, for public consultation, a five-year strategy to ban this practice across the province. The proposed strategy was not implemented, as public and stakeholder comments coupled with further analysis indicated limited potential for sufficient hauled sewage treatment capacity across Ontario at that time.

As part of the review of the Hauled Sewage Policy and Program review, initiated in early 2016, the MOECC is currently examining options for addressing environmental impacts and human health concerns associated with hauled sewage management, including its treatment, disposal and beneficial use. The ministry is considering a range of policy approaches, including a province-wide approach to deal with the land application of untreated hauled sewage, and geographically based restrictions, where there may be demonstrated hauled sewage treatment capacity at local municipal STPs or other facilities capable of treating hauled sewage. These considerations are still embryonic and no decisions have been made (Box 7).

BOX 7. POLICY REVIEW PROCESS IN CANADA.

The Ontario Ministry of the Environment and Climate Change in Canada is committed to ensuring that transparency, public consultation and engagement are central to this review. In addition to continuing to engage key stakeholders, such as municipalities, septic haulers, associations, landowners, community groups, etc., the ministry is establishing a multisectoral working group to support the policy and program review. All Ontarians will also have an opportunity to provide comments on the policy and program review being undertaken through the Environmental Registry. The ministry is committed to making informed evidence-based decisions. For this, the collection of data and information about how hauled sewage is currently managed within the province is taking place through engagement sessions and sector-specific surveys. This work will help the ministry to estimate

- Annual volumes of hauled sewage generated across Ontario;
- Volumes of hauled sewage treated vs. volumes disposed of without treatment;
- Current locally hauled sewage treatment capacities across Ontario; and
- Potential cost to develop adequate local capacities to treat hauled sewage.

The ministry is also in the process of evaluating the best available science regarding environmental impacts and treatment technologies as well as reviewing how other jurisdictions regulate and manage hauled sewage. This data-gathering step will support the ministry's efforts in developing new rules and guidance for treatment and land application of hauled sewage, based on the policy approach that is taken.

Source: MOECC 2017.

8. FRAMEWORK FOR DEVELOPING REGULATIONS AND GUIDELINES FOR FECAL SLUDGE MANAGEMENT

For a country, state or district to implement or improve FSM, proper regulations and technical/operational guidelines should be in place that are applicable to their context and supported by an enabling policy, finance and institutional environment to stimulate stakeholders to invest in, design and implement sanitation services and products (WSUP 2017).

Although **guidelines and regulations** differ significantly in how far they are legally binding, the FSM topics they have to address are similar. It is in this respect that the framework presented here can support the development of

both regulations and guidelines, and both terms are used concurrently, while it will depend on the user's context and objective what kind of document is targeted.

The framework builds on six modules (Figure 5), starting with an assessment of the existing situation of FSM in the particular national or other administrative boundary to understand context, challenges and responsibilities. Given that FSM cuts across different sectors along its service chain, a multidimensional and multi-actor approach is required throughout the development of any regulations (Koottatep et al. 2014).

Table 35 shows this framework for the structure of FSM guidelines and regulations, where each module will guide a chapter or section. The table was developed based on existing FSM policies, regulations, guidelines, manuals, etc. and should help to create the basis for a comprehensive regulatory document for proper and effective FSM with due attention to stakeholder processes and options supporting RRR within a circular economy.

FIGURE 5. KEY MODULES OF FSM REGULATIONS AND GUIDELINES WITHIN OSS.

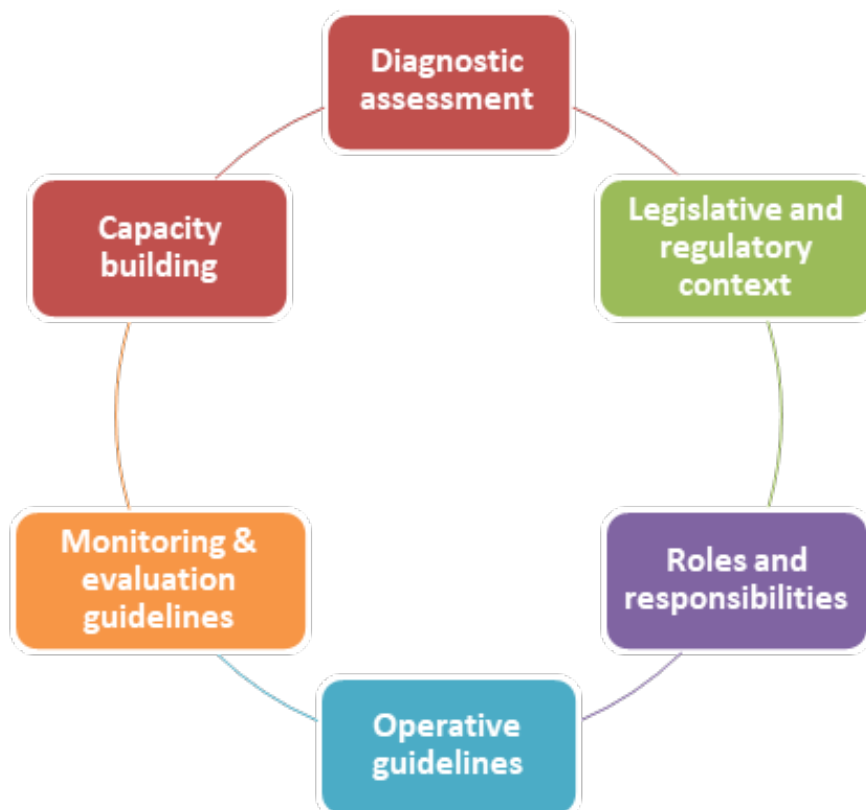


TABLE 35. MODULE CONTENT FOR CHAPTER DEVELOPMENT WITHIN FSM REGULATIONS AND GUIDELINES.

Chapter title and content	Reference within this report	External references
1. Diagnostic assessment		
<ul style="list-style-type: none"> Explore the sanitation situation and identify the problems Explore stakeholders' needs and perceptions Develop consensus on the need to develop/revise the FSM-related regulations/guidelines 	Chapter 1, Figure 2 Chapter 7, Box 7	CSE 2018; Eawag/ SANDEC 2002; NWASCO 2018; Government of India 2017; Government of Tamil Nadu 2017
2. Legislative and regulatory context: Regulatory assessment		
<ul style="list-style-type: none"> Identify the existing and missing regulations along the FSM service chain: Review policies, country-specific guidelines, strategies, plans and initiatives Identify the existing ordinances/penal provisions Identify the existing service standards/tariffs/fee structure Identify existing discharge and RRR requirements 	Chapter 1, Figure 2 Chapter 2, Figure 3	CSE 2018; NWASCO 2018; Government of India 2017; WSUP 2017; Koottatep et al. 2014
3. Roles and responsibilities: Institutional framework		
<ul style="list-style-type: none"> Identify the institutions involved in FSM and delineate their roles and responsibilities: Generate a FSM organizational chart delineating their roles and responsibilities Gap analysis for the roles and responsibilities: Identify gaps and overlaps but also needed cross-institutional linkages Provide knowledge on required interventions for identified gaps Develop options for alternative FSM institutional structure, e.g., with larger private sector involvement Define clear roles and responsibilities 	Chapter 1, Figure 2; Chapter 2, Tables 1 and 2, Figure 3	CSE 2018; NWASCO 2018; Government of India 2017; WSUP 2017; Koottatep et al. 2014
4. Implementation and operationalizing (operative guidelines)		
4.1. Technical guidelines: <ul style="list-style-type: none"> Introduce and/or improve the technical specifications for proper septic tank design Introducing and/or improve the existing guidelines for the collection, transport and treatment phases of FSM – guidelines for septic tank emptying services; measures to be taken during desludging of septic tanks; guidelines and regulations for private emptiers and informal emptiers, including the cost of services, methods and locations of transport; steps for planning of septage treatment facilities; guidelines for operation of treatment facilities Introduce guidelines on safe disposal and reuse of FS – safe land application, guidelines on different reuse options (reuse for agriculture, aquaculture, energy sectors (biogas, dry fuel) Identify decision-support tools to allow entrepreneurs to assess the technical and financial viability of various options and support the decision-making and investments in these contexts Introduce OHS guidelines along the sanitation value chain 	Chapter 3, Box 1, Tables 3, 4, 6, 7, 8; Chapter 4, Table 9, Section 4.2, Box 2, Table 11, Section 4.3, Section 4.4, Section 4.5; Chapter 5, Tables 16-19; Chapter 6, Figure 4, Section 6.1, 6.2 Tables 20-26, Box 4, Box 5, Tables 29-34	CSE 2018; Eawag and SANDEC 2002; Government of India 2017; Government of Tamil Nadu 2017; Koottatep et al. 2014; Saveyn and Eder 2014; WHO 2006a, 2006b, 2016

(Continued)

TABLE 35. MODULE CONTENT FOR CHAPTER DEVELOPMENT WITHIN FSM REGULATIONS AND GUIDELINES. (CONTINUED)

Chapter title and content	Reference within this report	External references
<ul style="list-style-type: none"> Develop health and safety guidelines for users, workers, farmers and communities at different stages of the sanitation value chain from user interface to reuse applications (drawing on guidelines from WHO publications on safe use of excreta and sanitation safety planning) 		
<p>4.2. Licensing, record-keeping, monitoring and reporting arrangements for FS and septage service providers</p> <ul style="list-style-type: none"> Define mechanisms for issuing license and (e.g., environmental, technical, safety) permits for collection, transportation, treatment, safe disposal and reuse of FS/septage (as compost or fuel) Define mechanisms for monitoring and reporting of service providers adhering to standards, regulation and guidelines – e.g., FS treatment standards, reuse regulations, different reuse product standards, etc. 	Chapter 2, Figure 3; Chapter 4, Section 4.4	CSE 2018; NWASCO 2018; Government of India 2017; Government of Tamil Nadu 2017; WSUP 2017; Koottatep et al. 2014
<p>4.3. Financing of FSM, financial reforms, current economies and business models</p> <ul style="list-style-type: none"> Identify financial subsidies from the government and other finance options (e.g., for RRR, see Lazurko et al. 2018) Add provision for private sector participation across the sanitation service chain, e.g., private sector participation through an easy and amenable public-private partnership relationship framework Introduce user charges to meet the O&M cost for effective FSM operations, e.g., households committed to paying semi-annual bill or monthly bills, start levying a sanitation tax Add penalties for violating the requirements: Penalty clauses for untreated discharge for households as well as desludging agents and unsafe emptying and handling of fecal waste Introduce tariffs or cess/tax, etc. for FSM Determine fees/charges for pit/tank emptying and transportation, truck desludging and sludge treatment 	Chapter 4, Tables 12, 13, 14, 15	CSE 2018; Eawag/ SANDEC 2002; NWASCO 2018; Government of India 2017; Government of Tamil Nadu 2017; WSUP 2017; Rao et al. 2016; Lazurko et al. 2018
5. Monitoring and evaluation guidelines		
<ul style="list-style-type: none"> Adopt service-level benchmarks for sanitation Introduce mechanisms for monitoring and evaluation of system performance – e.g., devise data collection and reporting systems using the indicator framework (Sanitation Service Benchmarking), record-keeping and reporting through management information systems Provision for continual improvement of FSM guidelines based on the information from monitoring and evaluation reporting, e.g., reuse regulations based on market demand, application guidelines based on agronomic trials, etc. 	Chapter 2, Tables 1, 2 Annex	CSE 2018; Eawag/ SANDEC 2002; Government of India 2017; Government of Tamil Nadu 2017

(Continued)

TABLE 35. MODULE CONTENT FOR CHAPTER DEVELOPMENT WITHIN FSM REGULATIONS AND GUIDELINES. (CONTINUED)

Chapter title and content	Reference within this report	External references
6. Capacity development of relevant stakeholders: Training, accreditation, education and awareness programs		
<ul style="list-style-type: none"> • Build institutional and personnel capacities and interlinked organizational systems for delivery of sanitation services • Integrate the FSM components in on-going capacity development programs • Incorporate a capacity-development component on various FS reuse options to promote the reuse of FS 	Chapter 2, Table 1	CSE 2018; Government of India 2017

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Annex: Proposed Sanitation Service Benchmarking Indicators for India

Proposed Sanitation Benchmark (Sewerage + Onsite systems)

1. Coverage of adequate sanitation system

Percentage of households with individual or group toilets connected with adequate sanitation systems (sewer network/septic tank / double pit system) to total households in the city.

2. Collection efficiency of sanitation system

Weighted average of collection efficiency of each sanitation system, weighted by share of households dependent on each sanitation system.

3. Adequacy of treatment capacity of Sanitation System

Weighted average of adequacy of treatment plant capacity available for each sanitation system, weighted by share of households dependent on each sanitation system.

4. Quality of treatment of sanitation system

Weighted average of quality of treatment of each sanitation system, weighted by share of households dependent on each sanitation system.

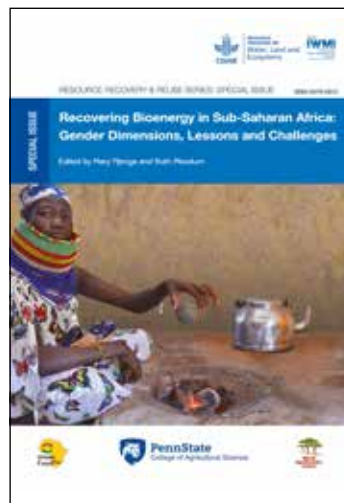
5. Extent of reuse and recycling in sanitation system

Weighted average of extent of reuse of treated wastewater and sludge after adequate treatment as a percentage of sewage and sludge received at the treatment plant, weighted by share of household dependent on each sanitation system.

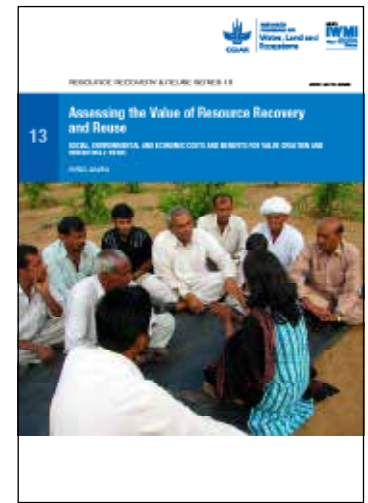
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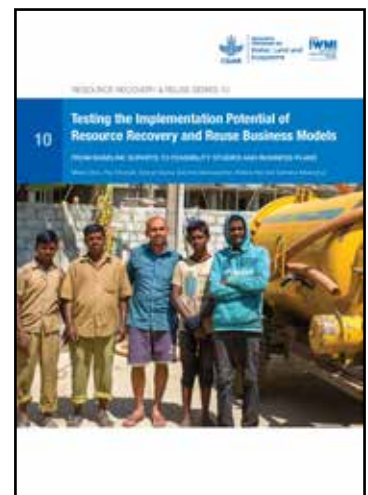
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RESEARCH PROGRAM ON
Water, Land and Ecosystems



CGIAR Research Program on Water, Land and Ecosystems

The **CGIAR Research Program on Water, Land and Ecosystems (WLE)** is a global research-for-development program connecting partners to deliver sustainable agriculture solutions that enhance our natural resources – and the lives of people that rely on them. WLE brings together 11 CGIAR centers, the Food and Agriculture Organization of the United Nations (FAO), the RUAF Foundation, and national, regional and international partners to deliver solutions that change agriculture from a driver of environmental degradation to part of the solution. WLE is led by the International Water Management Institute (IWMI) and partners as part of CGIAR, a global research partnership for a food-secure future.

Resource Recovery and Reuse (RRR) is a subprogram of WLE dedicated to applied research on the safe recovery of water, nutrients and energy from domestic and agro-industrial waste streams. This subprogram aims to create impact through different lines of action research, including (i) developing and testing scalable RRR business models, (ii) assessing and mitigating risks from RRR for public health and the environment, (iii) supporting public and private entities with innovative approaches for the safe reuse of wastewater and organic waste, and (iv) improving rural-urban linkages and resource allocations while minimizing the negative urban footprint on the peri-urban environment. This subprogram works closely with the World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), United Nations Environment Programme (UNEP), United Nations University (UNU), and many national and international partners across the globe. The RRR series of documents present summaries and reviews of the subprogram’s research and resulting application guidelines, targeting development experts and others in the research for development continuum.

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