UN environment programme

Faecal sludge management in Africa:

Socioeconomic aspects and human and environmental health implications

IWMI International Water Management Institute

CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

GWWI GLOBAL WASTEWATER INITIATIVE

Contents

Summary

This publication aims to explore how current trends in faecal sludge management are impacting human and environmental health in Africa (both sub-Saharan and Northern Africa). Faecal sludge comes from on-site sanitation technologies in the form of raw or partially digested slurry or semi-solid material. Its management involves storage, collection, transport, treatment and safe end use or disposal. Some factors that make it difficult to manage sustainably include population growth and urbanization, over-reliance on financial aid for the construction of treatment plants, low revenue generation from users of treatment facilities, poor operation and maintenance, and inefficient institutional arrangements for faecal sludge management.

Poor faecal sludge management poses major health, environmental and socioeconomic differential risks to men, women, boys and girls in Africa. Alongside poor sanitation, it contributes to the 115 deaths per hour from excreta-related diseases in Africa and huge economic losses.

Some good practices along the sanitation value chain that have been reported in a few countries have the potential for replication in several other African countries. Overall, there is a need to invest in sanitation systems and mechanisms to improve faecal sludge management and direct investments to very poor households. In particular, bottlenecks in service delivery pathways require urgent attention.

This publication examines faecal sludge management practices in Africa as a contribution to the joint project by the United Nations Environment Programme (UNEP), the African Development Bank (AfDB) and GRID-Arendal entitled Wastewater Management and Sanitation Provision in Africa: An Opportunity for Private and Public Sector Investment, which aims to promote knowledge on wastewater and sanitation in Africa, with the goal of enhancing these services across the continent.

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List of abbreviations

AfDB	African Development Bank
BOD	biochemical oxygen demand
BOD5	five-day biochemical oxygen demand
CFU	coliform forming unit
COD	chemical oxygen demand
COVID-19	Coronavirus Disease 2019
DW	dry weight
FAO	Food and Agriculture Organization of the United Nations
FS	faecal sludge
FSM	faecal sludge management
GDP	gross domestic product
GPA	Global Programme of Action
GW²I	Global Wastewater Initiative
INSD	Institut National de la Statistique et de la Démographie [National Institute of Statistics and Demography]
IWA	International Water Association
IWMI	International Water Management Institute
JMP	Joint Monitoring Programme
KCCA	Kampala Capital City Authority
NGO	non-governmental organization
ONEA	Office National de l'Eau et de l'Assainissement [National Water and Sanitation Office]
PPP	public private partnership
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SDG	Sustainable Development Goal
TSS	total suspended solids
UASB	up-flow anaerobic sludge blanket
UBOS	Uganda Bureau of Statistics
UKZN	University of KwaZulu-Natal
UNEP	United Nations Environment Programme
UNFPA	United Nations Population Fund
WASH	water, sanitation and hygiene
WHO	World Health Organization
WLE	Research Program on Water, Land and Ecosystems
WSP	Water and Sanitation Program
WUP	World Urbanization Prospects
WSUP	Water & Sanitation for the Urban Poor
WWTP	wastewater treatment plant

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1. Introduction

Of the two billion people lacking basic sanitation facilities globally, 300 million live in Africa (Joint Monitoring Programme, 2019). Only 7 per cent are connected to sewers and only 1 per cent of the waste is treated (World Health Organization (WHO), 2017). Nineteen per cent practise open defecation, while the remaining use on-site sanitation systems. Since the United Nations introduced the Sustainable Development Goals (SDGs) in 2015, the global community has focused on ensuring "access to water and sanitation for all" (SDG 6), a crucial cross-cutting issue to drive progress across several other goals in the 2030 Agenda for Sustainable Development. However, the challenges to achieving this goal include weak policy implementation and reforms, lack of financing by governments and other institutions in the sanitation sector, and an over-reliance on shared toilet facilities (Appiah-Effah *et al.*, 2019).

Faecal sludge originates from on-site sanitation technologies and is not collected via a sewerage system. It varies in consistency, quantity and concentration (Strande, 2014): it could be raw or partially digested, a slurry or semi-solid, and comes from the collection, storage and treatment of excreta and blackwater, with or without greywater. We define faecal sludge management as "the storage, collection, transport, treatment and safe end use or disposal of faecal sludge" (Penn *et al.*, 2018). This requires infrastructure and planning, which are lacking in many countries of Africa (Corcoran *et al.*, 2010). Where available, existing treatment facilities are often underutilized or overloaded, and release untreated or partially treated effluent[1] into the environment.

Poor sanitation has differential impacts on the health of men, women, boys and girls as well as broad economic and environmental implications. Access to sanitation facilities remains a challenge for urban populations in many sub-Saharan African cities, particularly for people living in poor peri-urban areas. Socioeconomic status and settlement characteristics are the main indicators of access to reliable water and sanitation in peri-urban settlements (Angoua *et al.*, 2018). While a lack of sanitation facilities reflects the lack of services in urban and peri-urban spaces, community members bear some responsibility for their environment and health. For example, unauthorized temporary structures, discharging wastewater and excreta into public spaces, dumping garbage near households, and open defecation all contribute to environmental and health risks (Angoua *et al.*, 2018).

The communities and social groups that people live in often determine their behaviour. For example, if a village identifies itself as 'open defecation free', it becomes difficult for an individual to be seen practising open defecation (Cross and Coombes, 2013). The history of settlement and land ownership is strongly correlated with willingness and ability to invest in household sanitation (Hirai *et al.*, 2018). Migrant status leaves people without land rights and hence little incentive to invest in sanitation (Awunyo-Akaba *et al.*, 2016). Furthermore, adoption of sanitation technology is dependent on many factors including design, cost, efficiency and functionality. Thus, sanitation products and services must be designed to motivate men and women to use them (Cross and Coombes, 2013). As meeting sanitation goals requires behavioural change as well as infrastructure improvements, any approach should involve local actors, administrative authorities and religious communities (Angoua *et al.*, 2018; J-PAL, 2012).

We define faecal sludge management as

"the storage, collection, transport, treatment and safe end use or disposal of faecal sludge"

(Penn *et al.*, 2018).

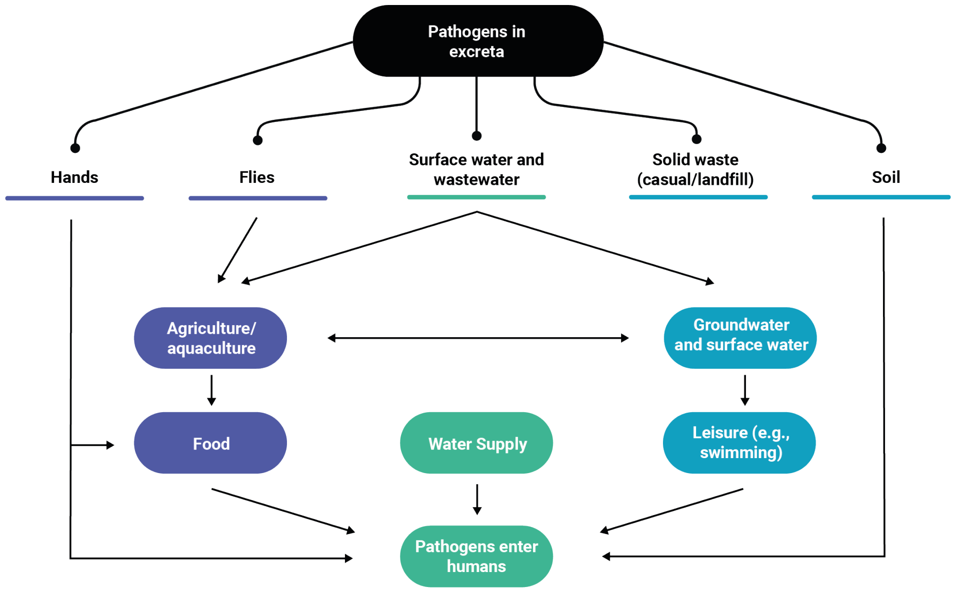
1 Effluent is the general term for any liquid that leaves a collection technology, typically after blackwater or sludge has undergone solids separation or another type of treatment.

Inadequate sanitation is the root cause of many tropical diseases, with improper faecal sludge management and poor sanitation contributing to the 115 deaths per hour from excreta-related diseases in Africa (Chowdhry and Koné, 2012; Mara *et al.*, 2010). Economic losses due to poor sanitation account for approximately 1 to 2.5 per cent of gross domestic product (GDP) on the continent and faecal contamination causes an annual average of 3,500 cases of cholera in Kenya and 1,800 in Ghana (World Bank, 2012). The cost of an effective water, sanitation and hygiene (WASH) response is estimated to be USD 2.2 million per year in Kenya and 1.2 million in Ghana (Water and Sanitation Program (WSP), 2012). The cost of not acting will have significantly more costly adverse effects on human health, the environment and the economy. Considering the 1 per cent at the lower end of estimates of economic loss from the World Bank and the GDP of Kenya of around USD 90 billion, then the economic loss is around USD 900 million. This is 450-fold greater than the USD 2.2 million cost for implementing WASH.

While faecal sludge is rich in nitrogen, phosphorus, potassium and organic matter, it also contains high counts of pathogenic coliforms, E. coli and helminth eggs (Pradhan, 2016; Strande *et al.*, 2014). Contact with as little as one gram of fresh faeces exposes a person to as many as 106 viral pathogens, 106–108 bacterial pathogens, 104 protozoan cysts or oocysts, and 10–104 helminth eggs (Thaku *et al.*, 2018).

Figure 1 illustrates the routes by which pathogens in excreta can be transmitted. It is widely recognized that only a small percentage of all faecal sludge produced is managed and treated appropriately (Peal *et al.*, 2014).

Figure 1. Transmission pathways of pathogens in excreta



Source: Franceys *et al*,. 1992

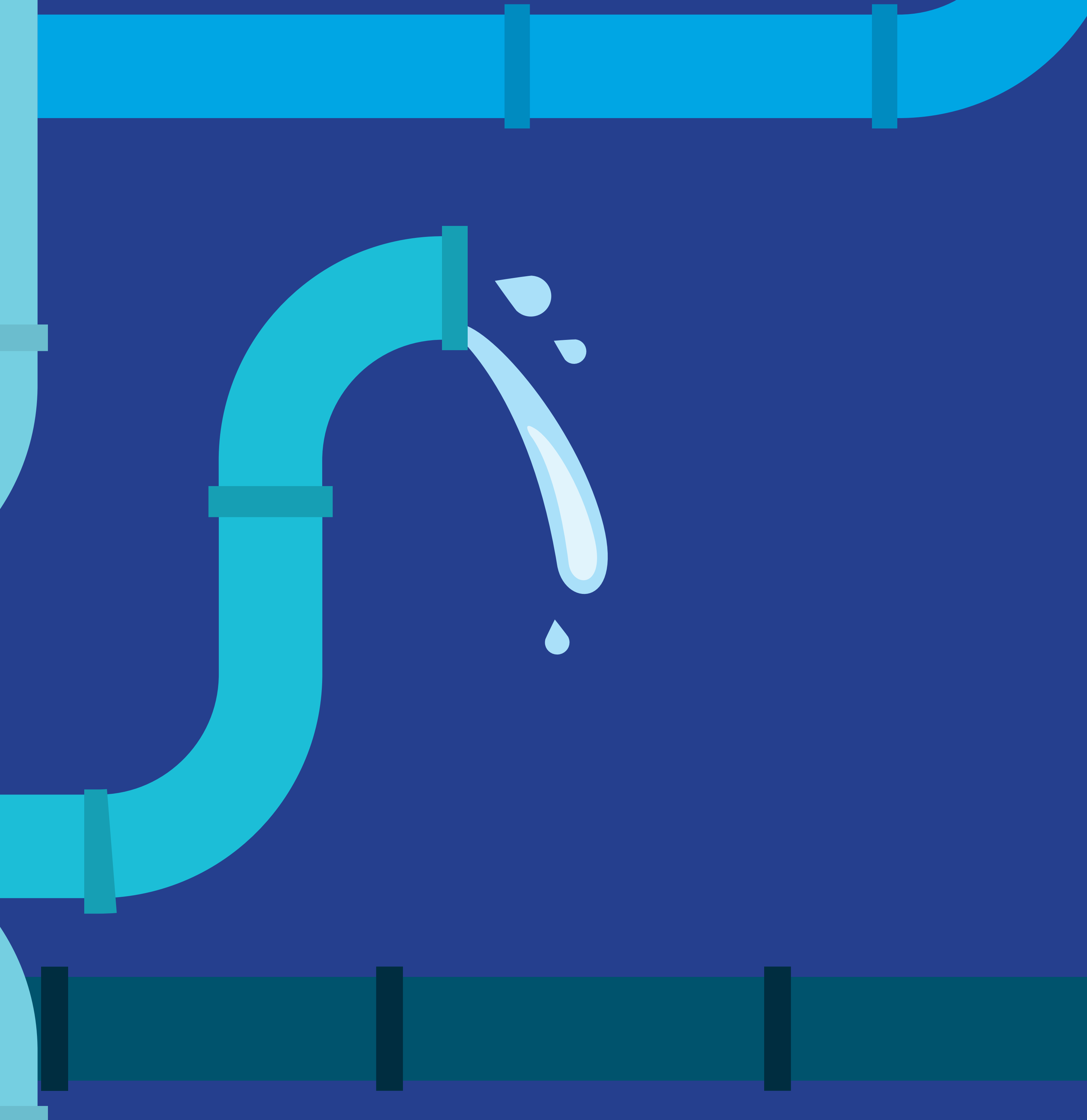
Minimizing health risks requires careful collection, treatment and disposal of faecal sludge. When untreated or partially treated faecal sludge is dumped in open canals or on agricultural land, it can pollute groundwater, surface water and soil. While the expansion of sanitation systems in Africa has helped reduce the volume of untreated sludge that is released into the environment, current practices for faecal sludge management need to improve.

African countries are working to meet SDG 6 on water and sanitation, which aims to i) achieve access to adequate and equitable sanitation and hygiene for all and end open defecation (SDG 6.2); and ii) improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally (SDG 6.3). SDG 6 is closely connected to several other SDGs, hence its achievement will greatly impact on the progress of others. For example, safe sanitation is crucial to reducing child mortality and deaths from excreta-related diseases (SDG 3). Reducing the time spent collecting water and improving school sanitation will enhance effective learning outcomes (SDG 4), especially among girls (SDG 5), and ultimately contribute to acquiring decent jobs and eradicating poverty (SDG 1 and SDG 8).

SDG sanitation targets go beyond measuring how many men, women, girls and boys have access to an adequate toilet and define outcomes in terms of safe human waste management across the service chain in all settlement contexts along the rural-urban continuum. To meet SDG targets by 2030, it will be necessary to improve sanitation services, including the safe handling, treatment, disposal and recycling of excreta (Tayler, 2018). This places immense economic pressure on poor countries (Farooq and Ahmad, 2017).

©IWMI - Worker turning compost heaps in Borteyman, Accra. Photo credit: David Brazie

2. Faecal sludge management and the sanitation challenge



2.1. Main constraints to sustainable management of wastewater and faecal sludge

The production of wastewater and faecal sludge is increasing with population growth, urbanization, rapid industrialization and changes in consumption (Corcoran *et al.*, 2010; Food and Agriculture Organization of the United Nations (FAO) and International Water Management Institute (IWMI), 2017). Over the past four decades, the urban population in sub-Saharan Africa has nearly quadrupled (United Nations Population Fund (UNFPA), 2016; United Nations, Department of Economic and Social Affairs, Population Division, 2015), while sanitation needs remain unmet (World Bank, 2016).

Faecal sludge and sustainable wastewater management are constrained by factors such as over-reliance on financial aid for the construction of wastewater and faecal sludge treatment plants, low revenue generation from users, poor operation and maintenance, and inefficient institutional arrangements. In some cases, there are deficient technical standards for the construction of facilities (Nikiema *et al.*, 2020; Bahri *et al.*, 2015). In some societies, only people of a certain social class enjoy the benefits of sustainable waste management.

2.2. Faecal sludge generation

The volume of faecal sludge and wastewater increases with population growth. In West Africa, faecal sludge generation is estimated at 100–1000 L per capita per year, and wastewater generation between 20 and 150 L capita-1 day-1. This value is projected to triple in the next 30 years according to World Urbanization Prospects (United Nations, 2019). Faecal sludge accumulation varies depending on the filling capacity of on-site sanitation facilities and the rate of addition or degradation (Foxon *et al.*, 2011). Accumulation rates also depend on the location, type of soil, number of users, and the period since the facility was last emptied (Koottatep *et al.*, 2014). Chowdhry and Koné (2012) reported faecal sludge accumulation for households with pit latrines to be 40 L capita-1 year-1, which translates to 0.1 L capita-1 day-1, whereas households with septic tanks accumulate 60 L capita-1 year-1 (0.16 L capita-1 day-1). In Burkina Faso and Ethiopia, where the on-site facilities are mostly pits, the accumulation rates are between 0.1 and 0.7 L capita-1 day-1, while in Senegal, septic tanks fill up at rates between 1.7 and 2.6 L capita-1 day-1 (Chowdhry and Koné, 2012).

2.3. Forms, composition, and implication for management

Faecal sludge is a mixture of human excreta, water and solid substances such as toilet paper or other cleansing materials as well as menstrual hygiene materials that are disposed of in pits, tanks or vaults of on-site sanitation systems. Nikiema *et al.* (2018) found that the chemical and physical characteristics of faecal sludge vary within and between different on-site systems and between locations, depending on user practices and moisture content and groundwater level where the system is situated (Buckley *et al.*, 2008; Graham and Polizzotto, 2013). Hence, solids concentration, chemical and biochemical oxygen demand (COD and BOD), nutrients, pathogens, and heavy metals composition should all be considered when planning sustainable faecal sludge management practices.

The characteristics of wastewater and faecal sludge differ somewhat (Strande *et al.*, 2014). Wastewater generally contains greater concentrations of pollutants such as microplastics, plastics, hormones and pharmaceuticals. Wastewater in Côte d'Ivoire, for instance, registers pollution from metallurgical, iron and steel industries producing heavy metals and hydrocarbons, along with pesticides and insecticides (Robin *et al.*, 2004). Table 1 illustrates high variability in faecal sludge characteristics compared with sludge from wastewater treatment plants.

Table 1. Examples of faecal sludge (FS) characteristics and comparison with wastewater

Parameter	FS Source		WWTP	Reference
	Public toilet	Septic Tank	sludge	
Total solids, TS (mg/L)	30,000	22,000	-	NWSC* (2008)
Total volatile solids, TVS (as percentage of TS)	68	50-73	-	Koné and Strauss (2004)
	65	45	-	NWSC (2008)
COD (mg/L)	49,000	1,2000- 7,800	-	Koné and Strauss (2004)
	30,000	10,000	7-608	NWSC (2008)
BOD (mg/L)	7,600	840-2,600	-	Koné and Strauss (2004)
	-	-	20-229	NWSC (2008)
Total Nitrogen, TN (mg/L)	-	190-300	-	Koné and Strauss (2004)
	-	-	32-250	NWSC (2008)

* National Water and Sewerage Corporation

Measured characteristics of faecal sludge are influenced by the sampling location (e.g. in pits or trucks), seasonality, pit characteristics and management systems (Buckley *et al.*, 2008), average desludging interval (Couderc *et al.*, 2008), soil physical properties such as soil permeability (Schoebitz *et al.*, 2014), and water table level (Zuma *et al.*, 2015). Table 2 shows selected characteristics of faecal sludge from different locations in Africa.

Table 2. Faecal sludge characteristics from different locations in sub-Saharan Africa

Study location	Sampling location	Parameter	Faecal sludge source		References
			Pit	Household septic tank (ST)	
Durban, South Africa	Pit	pH	4.7 – 8.6		Zuma *et al.*, 2015
Kampala, Uganda	Truck		7.0 – 8.7	5.7 – 8.9	Schoebitz *et al.*, 2016
Durban, South Africa	Pit	Total solids, TS (mg/L)	180,000 – 201,000		Zuma *et al.*, 2015
Kampala, Uganda	Truck		3,515 – 122,581	493 – 66,078	Schoebitz *et al.*, 2016
Ouagadougou, Burkina Faso	Truck		13,349 ± 10,755	8,984 ± 8,926	Bassan *et al.*, 2013
Durban, South Africa	Pit	Total volatile solids, TVS	23.6 – 82.5 as percentage of TVS		Zuma *et al.*, 2015
Kampala, Uganda	Truck		4,304 – 42,567 (mg/L)	826 – 54,919 (mg/L)	Schoebitz *et al.*, 2014, 2016
Accra, Ghana	ST		59 as percentage of TVS	68 as percentage of TVS	Koné and Strauss, 2004
Durban, South Africa	Pit	COD (mg/L)	16,729 – 224,373		Zuma *et al.*, 2015
Kampala, Uganda	Truck		6,740 – 100,017	742 – 91,850	Schoebitz *et al.*, 2016
Ouagadougou, Burkina Faso	Truck		12,437 ± 12,045	7,607 ± 6,718	Bassan *et al.*, 2013
Accra, Ghana	ST			7,800	Koné and Strauss, 2004
Accra, Ghana	ST	BOD5 (mg/L)		840 – 2,600	Koné and Strauss, 2004
Accra, Ghana	Truck		5,208	3,860	Nikiema *et al.*, 2018
Ouagadougou, Burkina Faso	Truck		502 ± 36		Nikiema *et al.*, 2018

Study location	Sampling location	Parameter	Faecal sludge source		References
			Pit	Household septic tank (ST)	
Benin	N/A	TKN (mg/L)		1,000	Katukiza *et al.*, 2012
	Pits		9,.3 – 74		Zuma *et al.*, 2015
Benin	Trucks		869 ± 353		Nikiema *et al.*, 2018
	Truck	NH_4-N (mg/L)	593 – 2,620	35 – 1,310	Schoebitz *et al.*, 2016
Yaoundé, Cameroun	Truck		80 – 3,300		Kengne *et al.*, 2011
Accra, Ghana	Truck		1,201	1,079	Nikiema *et al.*, 2018
Ouagadougou, Burkina Faso	Truck			29 ± 3	
Accra, Ghana	Truck		0.86	1.92	Nikiema *et al.*, 2018
Ouagadougou, Burkina Faso	Truck			44 ± 4	
Benin	Truck		490 ± 209		
Accra, Ghana	Pits and ST			≤ 1,000	Heinss *et al.*, 1998

Faecal sludge contains high counts of microorganisms originating from faeces, many of which are pathogenic. Direct and indirect contact with untreated faecal sludge poses a significant health risk via pathogens spread through an infection cycle that includes different stages and hosts (Strande *et al.*, 2014). The high concentrations of microorganisms and contaminants in human excreta are briefly described below (Cave and Kolsky, 1999; Williams and Overbo, 2015).

- Helminths are parasitic worms that infect and live off a host. Helminths eggs such as ascaris are abundant in faecal sludge (Yen-Phi *et al.*, 2010; Koné *et al.*, 2007) and can have devastating effects on human health, particularly in children. Ascaris eggs are hard and can survive for long periods in soil and pit sludge. They are an important indicator of faecal contamination, given their persistence in the environment.

- The most common pathogenic protozoa in human stools are Giardia, Cryptosporidium spp., Dientamoeba fragilis, Entamoeba spp. (including non-pathogenic species), Blastocystis spp., and Cyclospora cayetanensis (Fletcher *et al.*, 2012). Infections from protozoa are a main cause of gastrointestinal illnesses and waterborne diseases worldwide (McHardy *et al.*, 2014).

- Individuals excrete around 10^9 bacteria/g of faeces. Most are not pathogenic and actually contribute to effective functioning of on-site treatment systems through microbial degradation of faecal material. E. coli is used to assess the level of bacterial contamination in the environment because it is only able to grow in living bodies (Appling *et al.*, 2013).

- Over 100 types of viruses in human faeces can cause disease. They can be transmitted through consumption of, or contact with, contaminated food or water. Infected people excrete enteric viruses for long periods (2–3 months). Even those who are not clinically ill may excrete large numbers of such pathogens. An infected individual can excrete up to 10^6 viruses/g of faeces (Cave and Kolsky, 1999).

- Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is responsible for the coronavirus pandemic, which had infected over 50 million people by November 2020. The primary mode of transmission is through respiratory droplets, either through direct contact with an infected subject or indirect contact, through hand-mediated transfer of the virus from contaminated fomites to the mouth, nose or eyes (WHO, 2020). Detection of viable SARS-CoV-2 in the faeces of COVID-19 patients has been reported (Wang *et al.*, 2020; Wu *et al.*, 2020). Sun *et al.* (2020) also found infectious SARS-CoV-2 in the urine of one patient, while viral RNA has been found in sewage (Ahmed *et al.*, 2020). These detections raise the possibility of faecal-oral transmission, although the risk is generally low (Heller *et al.***,** 2020).

- Many contaminants such as pharmaceuticals and personal care products can be found in municipal wastewater (Gaze and Depledge, 2017) and eventually in the soil and water environment as organic materials. Although the nutrient and organic matter constituents of organic materials can provide agronomic benefits, the contaminants in them may pose some human and environmental health risks.

- The increasing use of antibiotics globally and the release of their residues into the environment is a health concern. Up to 30 per cent of antibiotics produced globally are consumed by humans and about 80 per cent of those are excreted through urine and faeces (Gaze and Depledge, 2017). Major wastes, including wastewater and faecal sludge, contain antibiotic residues and antibiotic-resistant bacteria. Although such antimicrobial concentrations in municipal wastewater effluent are generally too low to be toxic to exposed bacteria, in sufficient amounts they could cause antimicrobial resistance (Gullberg *et al.*, 2011). Furthermore, antimicrobials that are excreted in faeces and urine and used as soil amendments could potentially be absorbed into the food chain, including food of plant or animal origin (Rahube *et al.***,** 2014; Zhou, 2017).

  Recent studies show that the wastewater treatment process may help reduce antimicrobial bacteria load, but it has limited impact on antimicrobial-resistant genes which tend to persist in the environment (Fouz *et al.*, 2020). For example, wastewater used for urban agriculture in Ouagadougou, Burkina Faso contains a wide array of antibiotic resistance genes, thereby representing a high risk for spreading bacteria and antimicrobial resistance among the city dwellers (Bougnom *et al.*, 2019). Environmental bacteria and other contaminants can be mixed together with excreted antibiotics and resistant bacteria, which may exert further pressure on microbes accordingly, driving resistance to antibiotics. However, this is partly dependent on the level of environmental contamination and on how long antimicrobial residues persist in an active form (Gaze and Depledge, 2017).

"Up to 30 per cent of antibiotics produced globally are consumed by humans and about 80 per cent of those are excreted through urine and faeces"

(Gaze and Depledge, 2017).

> Existing mitigation strategies (through secondary and tertiary treatment) to reduce antibiotics and resistant bacteria from waste streams have shown variable levels of effectiveness, including unintended consequences such as toxic by-products (Pruden *et al.*, 2013; Gaze and Depledge, 2017). There is therefore a need for sustainable mitigation strategies as antimicrobial-resistant infections will likely become a leading cause of death globally by 2050 (O'Neil, 2014).

Improved sanitation has been shown to decrease diarrhoeal disease by 25 per cent, and there are also notable differences in its reduction depending on the type of improved water and sanitation implemented (Wolf *et al.*, 2018). The extent of pathogen reduction required is dependent on the intended disposal options and end use of treated sludge and liquid effluents. Table 3 shows the concentration of pathogens isolated from fresh faeces in different countries. These pathogens can be removed by biological treatment methods such as stabilization ponds, drying beds and activated sludge. Newer technologies for treatment, such as irradiation with gamma or electron beams, are possible but less widespread in their application.

Table 3. Selected pathogen concentrations in faecal sludge

Pathogen	Country	Septic tank	Pit latrines	Source
Faecal coliforms (CFU/100mL)	Ghana	2.6 x 105 – 6.8 x106	3.0 x 106 – 2.3 x108	Nartey *et al.*, 2017
	Uganda	1.0 x 105	1.0 x 105	NWSC, 2008
E. coli (CFU/mL or CFU/g DW)	Ghana	2.6 x 103 – 5.2 x104	2.2 x 104 – 2.6 x105	Nartey *et al.*, 2017
Helminth eggs (per L)	N/A	4,000 – 5,700	2,500	Heinss *et al.*, 1994
	Ghana	4,000	20,000 – 60,000	Heinss *et al.*, 1998

3. Trends in faecal sludge management along the sanitation service chain

Effective and sustainable management of faecal sludge requires sanitation to be addressed at all stages of the service chain (Figure 2). While sewerage systems combine containment, emptying and transport functions, on-site systems are emptied by mechanical suction or manual excavation and a truck transports the sludge to a treatment facility (WSP, 2014).

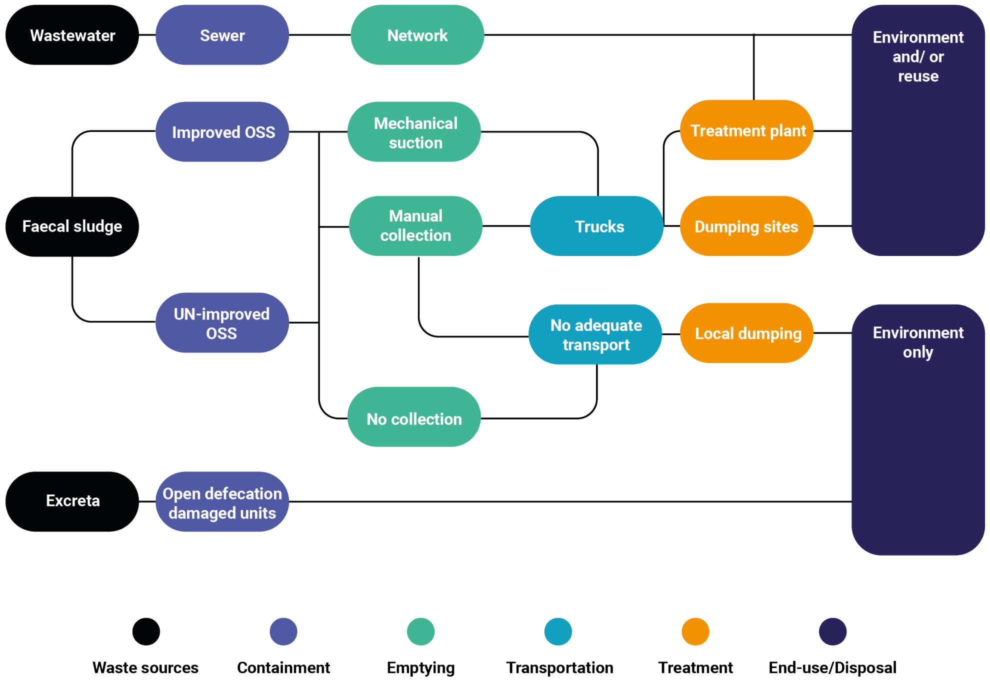


Figure 2. Management of faecal sludge, wastewater and excreta along the sanitation chain

Source: Nikiema *et al.*, 2015

3.1. Containment

Containment or faecal sludge capture is the starting point for management. According to Tayler (2018), containment technologies can be clustered into the following systems:

- hybrid systems, which retain solids on-site in a tank, while discharging liquid for off-site treatment
- on-site septic tanks, which retain solids, supernatant liquid and scum, and are regularly desludged
- pit latrines, which retain faecal sludge (only solid) in a tank and the partly digested faecal sludge is removed at infrequent intervals, depending on the size of the tank
- self-contained on-site systems, which retain faecal sludge and allow its on-site transformation into a safe material, able to be removed manually.

Different variations exist within each containment cluster. Holding tanks may be fully lined with impermeable walls and an open or sealed bottom. Pits may be lined or unlined. Faecal sludge retainers prevent faeces from spreading into the environment, thereby reducing the risk of contamination. They allow for pre- and subsequent treatment and facilitate collection, quantification and transportation (See photos in Annex 1; Nikiema *et al.*, 2018; Bassan *et al.*, 2013). However, some retainers – especially pit latrines and septic tanks – are poorly constructed and could increase the risk of surface and groundwater contamination with associated environmental and health risks (Peal *et al.*, 2013). In some cases, a lack of construction standards and poor supervision by local authorities has led to a proliferation of poorly performing containment systems.

3.2. Emptying, collection and transportation

Removal from on-site systems and transportation to a treatment or disposal facility are the second and third steps in the sanitation service chain for faecal sludge. Sludge can be removed by mechanical means or manually: the specific method depends on the type of containment system, the local climate, access to the site, the type of equipment used by the service provider, and their level of expertise (Mikhael *et al.*, 2014).

Manual collection methods are used most often in low-income communities and informal settlements. Manual emptying means faecal sludge is removed using basic tools such as buckets, shovels and ropes. Other collection methods are direct lifting, cartridge containment, and manually operated mechanical collection (sludge gulper, manually operated diaphragm pumps, Nibbler and MAPET2; Mikhael *et al.*, 2014). Manual collection methods have not been formally regulated in Africa. Although there are some informal associations that regulate the practice, standards for occupational health and safety are seldom enforced. The high demand for these services by low-income urban dwellers continues to sustain the status quo (African Water Association, 2017).

Fully mechanized emptying equipment can be mounted on a frame or trolley or directly onto the transport vehicle. Examples of mechanized methods are the motorized diaphragm pump, trash pump, pit screw auger, Gobbler, Vacu-Tug and the conventional vacuum tanker (See photos in Annex 1; Mikhael *et al.*, 2014).

Mechanical emptying is a faster and more efficient process. It is, however, restricted to middle- and high-income households with septic tanks and watertight tanks. Vacuum trucks often transport sludge to illegal dumping sites outside the city limits rather than authorized treatment stations. A study carried out in Burkina Faso, Nigeria and Senegal showed that about 60 per cent of households in cities used mechanical emptying, 34 per cent used manual emptying services, and less than 2 per cent a combination of the two (Chowdhry and Koné, 2012; Abiola, 2015; *Office National de l'Eau et de l'Assainissement* [ONEA], 2015). The frequency of emptying is, on average, once every two years, mostly by small private operators or self-financed entrepreneurs (Strande *et al.*, 2014; Chowdhry and Koné, 2012). The charge-out fees for emptying vary by country, region, market, volume and road condition, among other factors (Strande, 2014).

2 The Nibbler is a continuous, rotary action, displacement sludge pump. MAPET or Manual Pit Emptying Technology is a vacuum system for collection and short-distance transportation of sludge.

3.3. Treatment

After collection, faecal sludge is usually transported to faecal sludge treatment plants, where available. Treatment starts with separating the solid from the liquid through mechanical or biological means. Biological treatment includes stabilization ponds, drying beds and constructed wetlands, while mechanical treatment involves mechanized processes such as activated sludge, up-flow anaerobic sludge blanket (UASB) reactors, and anaerobic digesters. Many studies show that some faecal sludge treatment plants in Africa are not well maintained or managed and treatment performance is questionable. One underlying cause is the constant financial constraints encountered in these facilities. Unlike biological treatment, mechanical treatments are more expensive to operate, hence most African countries opt for biological methods (Tanoh *et al.*, forthcoming).

3.4. End use, disposal and recycling

After treatment, faecal sludge can be recycled in several ways (Gold *et al.*, 2016; Nikiema *et al.*, 2014; Diener *et al.*, 2014). Examples in Africa include using it as compost fertilizer in agriculture, including in Kenya, Rwanda, Ghana and Senegal (Cofie *et al.*, 2016; Adam-Bradford *et al.*, 2018). It can also be converted to biogas and electricity as piloted in Ougadougou, Burkina Faso, to briquettes for use as fuel instead of wood charcoal, or to biochar to sequestrate carbon for agriculture, as in Ethiopia (Woldetsadik *et al.*, 2017). Dry sludge can be used as fuel for industries (as was piloted in Rwanda) and as feed for aquaculture (as in Durban, South Africa).

3.5. Institutional arrangements and legal/ regulatory frameworks

Many actors have different roles and responsibilities in faecal sludge management, from primary local service delivery to high-level policy formulation. Based on the analysis of faecal sludge management business cases and models by Rao *et al.* (2016) from across Africa and Asia, the key stakeholders involved in access to toilets are households, businesses and institutions (public and private). The private and public sectors are responsible for emptying and transportation services, which may also involve civil society organizations (CSOs) in parallel. The Government manages treatment services, although in some cases the private sector plays a role in faecal sludge treatment, usually through public private partnership arrangements. NGOs and community-based organizations (CBOs)/CSOs usually lead in creating awareness of faecal sludge-based reuse products and marketing them. There are designated ministries with specific roles and regulation frameworks for sanitation and it is common to find a decentralized government structure for sanitation service delivery (African Water Association, 2017).

Rao *et al.* (2016) identified the financial transaction and regulations in faecal sludge management along the sanitation value chain in different countries. Sanitation tax is the fee paid by on-site sanitation beneficiaries to the local authority towards the treatment of faecal sludge. Collection fees are charged to customers for the collection and transportation of faecal sludge. The private enterprise pays licence fees to obtain a permit from the local government to operate their business. Disposal fees are charged by the private emptying entrepreneurs for sludge disposal. Private enterprises also receive incentives to motivate them to deposit sludge at the selected disposal sites.

In Maputo, the Water and Sanitation Infrastructure Board for Mozambique (AIAS) is the national agency responsible for sanitation services, infrastructure and capacity-building in the urban areas, under the Ministry of Public Works, Housing and Water Resources. The Water Regulatory Council (CRA) is in charge of regulating sanitation services, while the Maputo Municipal Council (MMC) provide sanitation services, including faecal sludge management, to households. Private enterprises are involved in the collection and transportation services (Muxímpua *et al.*, 2017)

In the city of Kampala, Uganda, faecal sludge emptying and transportation is carried out by the private sector, while the public sector (National Water and Sewerage Corporation, NWSC) manages the treatment plant. Regulations on faecal sludge transportation and disposal are enforced by the National Environmental Management Authority. NGOs and CBOs are responsible for the provision of sanitation services (Nkurunziza *et al.*, 2017). The case of Kumasi, Ghana is slightly different. The Environmental Protection Agency serves as the regulatory body, while Kumasi Metropolitan Assembly (KMA) provides sanitation services, including collection and disposal of faecal sludge. Faecal sludge collections are carried out by this public institution and private companies. In particular, the Waste Management Department of KMA provides manual emptying services to traditional pit owners. In Ghana and Burkina Faso, the private sector is involved in the entire sanitation service delivery chain (Chowdhry and Koné, 2012).

As faecal sludge management is a cross-cutting issue, the key sectors of environment, health, water, urban planning and development need to be involved. However, the lack of clarity in institutional responsibility as well as limited legal and regulatory frameworks constrain effective faecal sludge management. In such situations, uncoordinated action could hamper effective sanitation service delivery. A generic institutional, regulatory and financial framework in faecal sludge management along the sanitation chain is presented in Figure 3.

	Access to toilet	Emptying and transport	Treatment	Disposal or reuse
Institutional arrangement (stakeholders involved)	Households, government and private institutions, businesses	CBOs, NGOs, emptier association, municipalities, private companies	Private companies, municipality and public utility	Government institutions, farmers, small businesses, CBOs/NGOs and microenterprise
Legal framework	Building codes for on-site sanitation; permits on construction; regulations on taxation or user charges; inspection of pits/tanks	Regulation on emptying and disposal; sanitation clearance; licence for emptying operators and motor cycle; guidelines for desludging and transportation	Standards for treatment; procedures for septage treatment; inspection of treatment plant; maintenance of records and reporting	Standards for treatment; standards for reuse based on type of reuse product; environmental clearance for designated disposal site
Financial framework	Sanitation tax and collection fees	Operation and maintenance; capital, licence fees, licence permits	Capital, operation and maintenance support and sanitation tax revenue	Disposal incentives and fees

Figure 3. Institutional, regulatory and financial framework in faecal sludge management along the sanitation value chain

Source: Adapted from Rao *et al.*, 2016

SuSanA Secretariat - Vacuum tanker for emptying of septic tank, Burundi

SuSanA Secretariat - Waste disposal in a neighbourhood of Bujumbura, Burundi

4. Good practices in faecal sludge management

Several cities in sub-Saharan Africa are implementing some good practices in faecal sludge management that could be replicated in other countries. A few of these cases across West, East and Southern Africa are presented in the following section.

4.1. West Africa

Dakar, Senegal

Until recently, faecal sludge management in Dakar was associated with an unregulated market for mechanical emptying services, outmoded vacuum trucks and poorly functioning treatment plants, which combined to result in poor disposal and recycling of sludge. These practices reduced the economy of scale in reuse and increased the repair and maintenance of vacuum trucks.

In 2011, the Programme for Structuring the Faecal Sludge Market was initiated to make faecal sludge emptying and transportation more efficient, upgrade the treatment plants and improve service delivery. The programme introduced a guarantee fund which facilitated the purchase of 26 vacuum trucks, which were regulated and certified in order to improve service quality in the city. A call centre was opened to provide easy access to mechanical emptying services and resulted in high service demand for operators, while the emptying price was reduced by 20 per cent. The treatment plant was managed by private operators, with the dry sludge sold to the agricultural market. The programme's uniqueness lies in its call centre model for mechanical emptying services. This is replicable in other cities and countries, but it must be accompanied by a sustainable business operation that fits the local market context of the individual countries.

Based on Diop and Mbéguéré (2017)

Ouagadougou, Burkina Faso

Ouagadougou is the capital city of Burkina Faso. With approximately 2.5 million inhabitants, it accounts for about 14 per cent of the nation's population and is growing at a rate of 3 per cent per annum (Water & Sanitation for the Urban Poor (WSUP), 2014; Institut National de la Statistique et de la Démographie (INSD), 2013). Less than 2 per cent of the population are connected to the sewer network. The remaining 73 per cent use pit latrines and 15 per cent use septic tanks for faecal sludge containment in Ouagadougou (ONEA, 2015). Fifty per cent of on-site systems in Ouagadougou have been emptied since they were built: 75 per cent by vacuum truck and 25 per cent manually (Burkina Faso, Direction générale de l'assainissement des eaux usées et excreta (DGAEUE) 2011). City-wide, 324 m^3 of faecal sludge is collected and received at treatment plants each workday (Nikiema *et al.*, 2018).

Ouagadougou has three functional faecal sludge treatment plants, equipped with drying beds to separate liquids and solids and ponds to treat liquids. In 2017, Burkina Faso progressed in faecal sludge management by commissioning the first faecal sludge biogas plant in the country, located at Kossodo, to generate 2,160 MWh year-1 of electricity to feed the national grid (ONEA, 2017). The country has a unique institutional arrangement for faecal sludge management that involves different levels of institutional actors with distinctive roles and responsibilities (Figure 4).

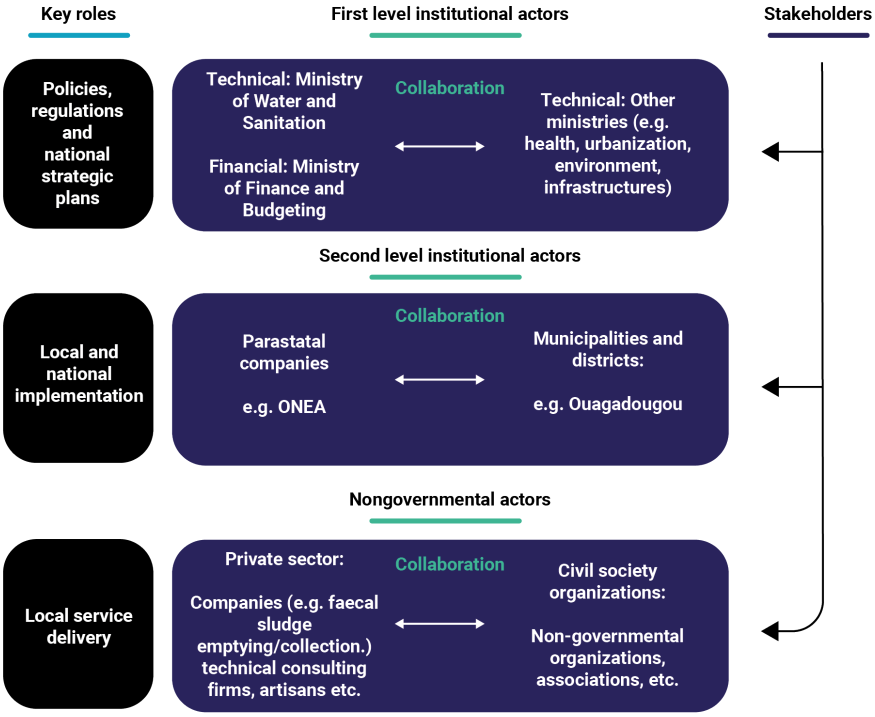


Figure 4. Institutional arrangements for sanitation in Burkina Faso

Source: Nikiema *et al.*, 2018

SuSanA Secretariat - Advert for septic tank emptying, Burundi

4.2. East Africa

Kampala, Uganda

Kampala, the capital city of Uganda, is the most populous urban centre in the country with 1.5 million people representing 5 per cent of Uganda's population (Kampala Capital City Authority [KCCA], 2019). Over 60 per cent of Kampala's population live in slums (Uganda Bureau of Statistics (UBOS), 2005). Faecal sludge in Kampala is contained mainly in septic tanks and pit latrines and sludge is removed either manually or mechanically. Emptying, collection and transport services are provided by the Kampala Capital City Authority (KCCA) as well as informal and unregulated private operators using vacuum trucks or 'gulpers'. In informal settlements, faecal sludge is collected but not treated and much of it is dumped into open water bodies or back into the drainage system (Jones *et al.*, 2013; O'Keefe *et al.*, 2015).

The city has two wastewater treatment plants: Bugolobi Sewage Treatment Works and Lubigi Sewage and Faecal Sludge Treatment Plant. Some initiatives that combine sludge treatment with reuse are emerging. In Kampala, there was a free market for emptying services as faecal sludge management was unregulated. Private operators therefore negotiated charges with customers and only paid for dumping fees at the treatment plants. There were no defined geographical boundaries, so operators offered their services based on proximity and willingness to pay. The KCCA therefore developed a programme to improve faecal sludge management in the city. The objectives were to create a robust legal and institutional framework with clear roles and responsibilities, involve the private sector in business development, increase service coverage, efficiency and affordability in emptying services, and create awareness and build capacity among stakeholders along the sanitation service chain.

KCCA divided the city into operational zones to increase city-wide coverage. Private operators received licences from the National Environment Management Authority and were granted a territorial concession from KCCA. The pit emptiers received revenue from their customers and paid dumping fees at the treatment plant to the National Water and Sewerage Cooperation. NGOs and CBOs helped KCCA create awareness and increase demand. Additional innovations were created to improve faecal sludge management in the city: a sanitation call centre was established to strengthen the link between customers, KCCA and the private operators. Furthermore, a GPS tracking system was established for private operators to improve service efficiency and avoid illegal dumping. Mobile transfer stations further reduced transportation distance for small-scale private operators.

Source: Nkurunziza *et al.*, 2017

4.3. Southern Africa

eThekwini municipality, Durban, South Africa

eThekwini has a population of 3.6 million inhabitants, with 60 per cent living in rural areas. About 150,000 households in Durban are in informal settlements without a connection to the sewer system. Faecal sludge collection in Durban, especially in rural and peri-urban areas, is very challenging. The city applies a broad mix of technologies and implements several innovative strategies to manage faecal sludge along the service chain. A private-sector partnership business model was developed for emptying and disposal, thereby encouraging business development. This model allows burial of faecal sludge on-site or transportation to a Black Soldier Fly Processing Plant, where the end products include biochar, animal feed and oil. Through the tested faecal sludge management solutions, the city has learned crucial lessons, including the fact that 'one size does not fit all'. Beyond appropriate toilet technology, continuous engagement with stakeholders, education and sustained research will support the re-imagining of faecal sludge management solutions.

Source: Gounden and Alcock, 2017; Sindall *et. al.*, 2018

Maputo, Mozambique

In response to the main constraints of regulation, financing and monitoring relating to the sanitation service chain in Maputo, the Maputo Municipal Council (MMC) developed a legal and regulatory framework to improve sanitation services. This involved endorsing new sanitation laws that address faecal sludge management, as well as rolling out related service provision using private operators and sanitation tariffs. The business model for faecal sludge management was designed around transfer stations to allow the primary collection of relatively small volumes of sludge from pit latrines using small equipment to remove sludge through narrow alleyways, before carrying out secondary transport from transfer stations using larger equipment. Maputo operators were contracted by the MMC, which provided them with stable income. The model was successful as it incorporated the established solid waste collection business in the communities into a new faecal sludge management business operation based on the pre-existing model. Sanitation marketing through television campaigns also had a substantial impact on acceptance of the improved emptying services.

Source: Muxímpua *et al.*, 2017

5. Environmental and health implications of faecal sludge management

©Martina Winker on Flickr 2012 - Emptying of vacuum tanker in Burundi

5.1. Containment

Many households in Africa (for example, 89 per cent in Maputo, 90 per cent in Kampala, 73 per cent across Burkina Faso) use substandard pit latrines as their main faecal sludge containment method because of their low cost (Tayler, 2018; WSP, 2014). Most of these latrines have no physical barrier to prevent seepage, resulting in contamination of surrounding soil and groundwater resources. Poorly constructed septic tanks may have the same issue (van Ryneveld and Fourie, 1997). Water-related diseases such as diarrhoea, cholera and dysentery are common in Africa. Diarrhoeal disease – which is the second leading cause of death in children under five years old – can be prevented through adequate sanitation, in addition to safe drinking water and hygiene.

Pit latrines can be an effective means of containing human waste, but storage conditions often lead to nitrification. The potential for nitrate pollution from pit latrines can be significant where there are shallow aquifers (Templeton *et al.*, 2015). Due to the high concentration of nitrogen in human excreta, nitrate is the most widely investigated chemical contaminant from pit latrines. Nitrate pollution from pit latrines can enter the drinking water source and cause methemoglobinemia,[3] which is linked to cancer in humans (Fewtrell, 2004; WHO, 2011). Nitrate soil contamination can be the result of other human activities or a function of soil composition, but its presence in drinking water sourced near pit latrines should be considered an indicator of faecal contamination (Graham and Polizzotto, 2013). Table 4 lists studies that have assessed chemical and microbial contaminants and estimated the risk related to pit latrines.

Table 4. Selected studies assessing groundwater or soil contamination associated with pit latrines

Country	Number of latrines	Water quality parameters	Distance from well to latrine	Conclusion	Source
South Africa	15	Ammonia, nitrate, nitrite	< 11 m from pit latrines	Higher levels of contaminants	Vinger *et al.*, 2012
Benin	220	Adenovirus, rotavirus		Viral contamination of groundwater	Verheyen *et al.*, 2009

3 Methemoglobin is a form of hemoglobin. Hemoglobin is the protein in red blood cells that carries and distributes oxygen to the body. Methemoglobinemia is a blood disorder in which an abnormal amount of methemoglobin is produced.

Country	Number of latrines	Water quality parameters	Distance from well to latrine	Conclusion	Source
Zimbabwe	3	Ammonia, nitrate, turbidity, pH, conductivity, total coliforms, faecal coliforms	> 5 m from pits	Faecal coliform movement greatly reduced. All nitrate levels and 99 per cent of ammonia levels met WHO drinking water standards	Dzwairo *et al.*, 2006
Zimbabwe	Not specified	Na, Zn, Cu, Co, Fe, phosphate, nitrate, total coliforms, faecal coliforms		Elevated levels of nitrate and coliform bacteria in most parts of the study area	Zingoni *et al.*, 2005
Botswana	Not specified	A broad set of hydrochemical analyses		Elevated levels of nitrate in several zones where pit latrines were common	Mafa, 2003

Source: Graham and Polizzotto, 2013

5.2. Collection and transportation

Different methods of emptying faecal sludge can affect environmental and human health. Figure 5 highlights the transmission pathways of contaminants. When emptying septic tanks or pit latrines, sanitation workers may contaminate the household environment and put lives in danger. Most sanitation workers do not wear personal protective equipment, whether through choice or lack of financial means. Photos A9 and A10 in Annex 1 show unprotected sanitation workers emptying, collecting and transporting faecal sludge.

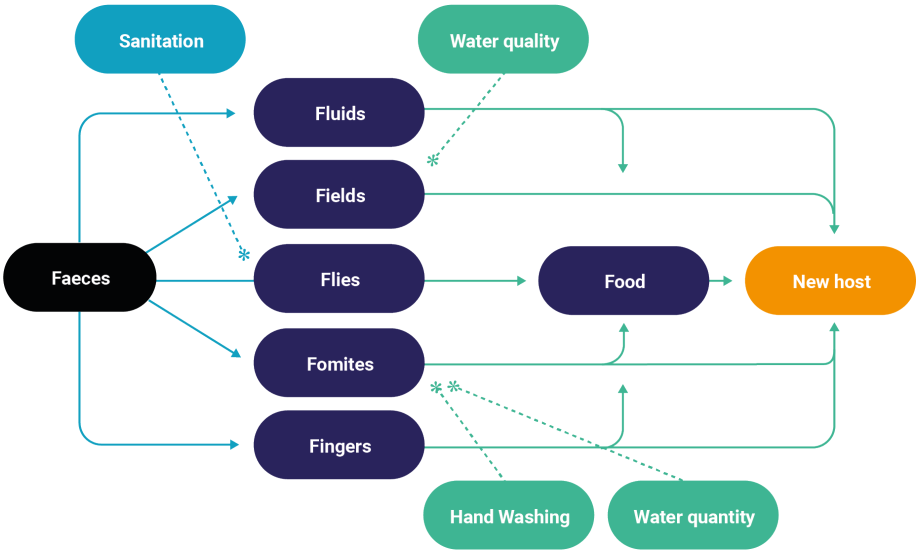


Figure 5.
Transmission routes for faecal-oral infections and the role of water, sanitation and hygiene in preventing transmission

Source: Cairncross and Feachem, 2019

Hygienic methods for emptying pit latrines include the use of vacuum tankers or the Vacu-Tug (Photos A5 and A7, Annex 1). Unhygienic methods include pit diversion, the use of buckets or 'flooding out'. Jenkins *et al.*, (2015) demonstrated widespread use of pit diversion (78 per cent), followed by tankers (58 per cent) and buckets (56 per cent) in Dar es Salaam, Tanzania. They attributed these findings to physical and economic access to safe services for emptying pit latrines. It is not clear how much faecal sludge remains uncollected and buried in pits in African cities. A recent study in Blantyre, Malawi revealed that most discharged sludge is taken from a small proportion of septic tanks in the city, while sludge from pit latrines (the most common sanitation technology) remains uncollected (Yesaya and Tilley, 2020). These findings support the need for appropriate businesses and infrastructures for faecal sludge management, including sustainable financing mechanisms to subsidize emptying services, which would make payment more affordable and encourage regulatory efforts to promote safe services (Jenkins *et al.*, 2015).

5.3. Faecal sludge treatment plants

Biological or mechanical treatment plants play an important role in the sanitation chain. Treatment plants reduce the water content of faecal sludge, which constitutes over 95 per cent of faecal sludge collected by vacuum trucks. Dewatering is known to reduce sludge management costs by reducing the sludge to biosolid so that it can be handled with spades or used as fertilizer (Gold *et al.*, 2016). It is also possible to reduce biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS) content of the liquid fraction through waste stabilization ponds. Reducing these parameters would help preserve aquatic life by avoiding the depletion of oxygen levels or a build-up of solids. Pathogens from liquid effluent and sludge are reduced in treatment and allow its safe disposal into the environment or end use in agriculture (Tayler, 2018).

Unfortunately, treatment facilities in Africa are not well maintained or managed. A lack of sustainability in terms of their operation, maintenance and monitoring affects treatment performance and constitutes a threat to public health and the environment.

In Kampala, Uganda, a study assessed health risks from wastewater, faecal sludge management and the reuse chain in agriculture. The findings show that farmers were at greater risk (prevalence of infection 75.9 per cent) than wastewater treatment plant workers (41.9 per cent) and faecal sludge collectors (35.8 per cent). The stream receiving the treated wastewater was contaminated by E. coli and hookworm eggs, with concentrations exceeding WHO standards for reusable wastewater in agriculture (between 3.8 x105 and 9.9 x 104 CUF/100 mL; Fuhrimann *et al.*, 2014).

As reported by Murray and Drechsel (2011), a study on the cost of operations, maintenance and monitoring of five treatment plants in Ghana showed they do not have the necessary equipment to ensure effective treatment of the faecal sludge or leachate they receive. Plant operation, performance and effluent content are, in many cases, not monitored. Plants older than 10 years usually experience technical issues, from disrepair of some equipment that has never been replaced to malfunctioning of process components, such as weighbridges. One reason for these irregularities is the unsatisfactory tipping fees collected at treatment plants, because they are not high enough to ensure operations, maintenance and monitoring costs (Tanoh *et al.*, forthcoming).

The findings show that farmers were at greater risk (prevalence of infection 75.9 per cent) than wastewater treatment plant workers (41.9 per cent) and faecal sludge collectors (35.8 per cent).

(Fuhrimann *et al.*, 2014).

©IWMI - Briquette press in use in Ghana. Photo credit: Hamish John Appleby

6. Societal and economic impacts

Sustainable management of faecal sludge improves human and environmental health and generates societal and economic benefits. Although the goal of sanitation agencies is to improve health, households rarely use toilets for health-related reasons alone; their primary concern is a desire for privacy. Most households aspire to some concept of 'modernity' and social acceptance and want to avoid the discomfort and dangers of open defecation (Jenkins and Scott, 2007). In general, faecal sludge management has gender implications at different levels. For example, the construction of latrines reduces the risk of women being attacked and raped when going to the bush or public toilets to defecate (Mara *et al.*, 2010). Some perspectives on gender and social inclusion in faecal sludge management are presented in the box on gender and social inclusion.

Gender and social inclusion in faecal sludge management

Men, women, boys and girls have different biological and social needs that determine their sanitation requirements. Women who serve as caretakers of the young, sick and elderly in their society carry an additional indirect burden of disease that negatively impacts them. Women's responsibility affects how, when and where they may meet their sanitary needs. Lack of access to sanitation facilities has a differential impact on gender due to expectations regarding modesty and personal security. Quite often, when deciding where to construct public toilets, there is little consideration of the fact that women need greater privacy as well as security from the risk of harassment.

Some studies have reported that inaccessible sanitation designs force people with physical impairments to crawl on the floor to use a toilet or opt to defecate in the open. A high proportion of vulnerable household members have been found to be very reliant on others to use the toilet, sometimes soiling themselves while waiting, and many limit their consumption of food and water to reduce the need to relieve themselves (Wilbur and Jones, 2014). There are reported cases, though the exact estimate is not known, of people with disabilities being considered contagious and therefore prevented from using communal toilet facilities (Wilbur and Danquah, 2015). Unavailability of good sanitation facilities can lead to psychosocial stress for girls, whereas access to good sanitation reduces child mortality and death while supporting maternal and neonatal health.

The back-end of the sanitation system tends to employ the most marginalized members of society e.g., those who service public toilets. Marginalization of people who are employed in pit emptying, transportation and disposal of faecal sludge has been observed in sub-Saharan Africa (Burt *et al.* 2016), though it may not be as high as in South Asia.

Faecal sludge management is not gender-neutral and could in fact deepen gender inequalities if not handled appropriately. Unfortunately, the related gender-disaggregated data needed to inform policy and practice in sustainable faecal sludge management are lacking. Interventions must be based on a good understanding of gender-specific needs and, in particular, the constraints faced by women and girls in accessing safe sanitation. Gender inequality embedded along the faecal sludge management chain may require technological as well as policy changes. Therefore, investments in sanitation systems must consider the design and implementation of gender-responsive faecal sludge management, which can further serve as a catalyst for achieving SDG 6.

Faecal sludge management has economic impacts across the sanitation chain.

Access and containment: Access to toilet facilities is beneficial to households in terms of improved health status and gains in time saved for productive activities (Trémolet, 2013). Revenues are generated through tariffs and taxes to the Government and service providers. Meanwhile, the use of unimproved toilet facilities causes economic losses due to the cost of treating illnesses that result from poor sanitation, and the loss of income through reduced productivity. The study conducted by van Minh and Nguyen-Viet (2011) on the economic impacts of poor sanitation in 18 African countries revealed that almost USD 5.5 billion are lost each year due to unimproved assess to sanitation. In Burkina Faso and Ghana, the cost of premature death and health care due to unimproved sanitation is estimated at USD 136 million and USD 54 million each year, respectively (Cross and Coombes, 2013). In Niger, where about 79 per cent of the population practise open defecation, the time cost to access these areas is estimated at USD 23 million every year (van Minh and Nguyen-Viet, 2011).

Emptying and transport: Enormous revenue is generated by the various service providers that are active in this segment of faecal sludge management. In Kampala, Uganda, where faecal sludge collection and transportation is largely carried out by unregulated private operators, vacuum truck operators charge at least USD 20.00 for 2.5m^3 and USD 50.00 for 10m^3 of faecal sludge (Nkurunziza *et al.,* 2017). In Abuja, Nigeria, up to 2,000 emptying trips are made per year in total at an average emptying fee of USD 88. One study reported for Dakar, Senegal, an approximate charge of USD 50 per trip for a domestic emptying service, while the commercial emptying charge ranged from USD 100 to USD 160 per trip (Mbéguéré *et al.,* 2010). Emptying faecal sludge remains a challenge in many cities as low-income households are not able to afford the service. For example, in Maputo, Mozambique, manual latrine emptying – which ends up being buried or dumped in drainage systems – costs a minimum of USD 13 per service, which is four times less than the cost of mechanical emptying (Hawkins and Muxímpua, 2015).

Treatment, disposal and reuse: There is a general lack of faecal sludge treatment facilities in many African countries for financial reasons. Where available, existing facilities lack the capacity to treat the volume of faecal sludge generated or are very expensive to maintain. For example, in Addis Ababa, Ethiopia, the treatment plant has the capacity to receive only 67 per cent of the 530,000 m^3 sludge collected annually (Chowdhry and Koné, 2012). Operation and maintenance costs for a treatment plant in Ghana average about USD 100,000 annually, whereas in countries such as India this could be as low as USD 40,000 (Rao *et al.* 2016). Countries such as Benin, Gabon and Mali have treatment facilities owned and operated by private companies (Bassan, 2014), while public private partnership (PPP) arrangements are common in most other countries.

Transforming faecal sludge into useful products through a circular economy approach is increasingly becoming an alternative way of treating faecal sludge in the continent. A study conducted by Diener ***et al.*** (2014) identified five potential faecal sludge transformation products in Senegal, Ghana and Uganda: (a) dry combustion fuel, which constitutes a potential market in the industrial sector (b) animal protein (c) biogas (d) building materials and (e) as a soil conditioner.

Several business models to effectively transform faecal sludge into useful materials have been developed and tested (Otoo and Drechsel, 2018). For example, in Nairobi, faecal sludge is sold at USD 1.25 to USD 1.45 per ton directly to farmers and to biocentres to generate biogas for cooking (Chowdhry and Koné, 2012). The municipal treatment plant in eThekwini, South Africa produces oil from larvae, animal feed and biochar, which are sold to farmers and industry (Gounden and Alcock, 2017). In this regard, the role of the private sector becomes crucial and there are opportunities for investment and partnerships in terms of technology and research that can be deployed for scaling successful models of faecal sludge transformation.

Overall, poor faecal sludge management is associated with economic losses which can be expressed in terms of health-care cost, productivity cost, mortality and time lost searching for access to good sanitation. Conversely, the economic benefit of faecal sludge management includes direct health gains such as health-care cost averted, economic benefits of avoiding illnesses, as well as the indirect economic benefits such as decrease in workdays lost to illness or workday productivity gains (van Minh and Nguyen-Viet, 2011).

©IWMI - A worker in agroforestry in Egypt. Photo credit: Javier Mateo-Sagasta

©IWMI - Borteyman Worker checking sludge on a drying bed, Ghana. Photo credit: Hamish John Appleby

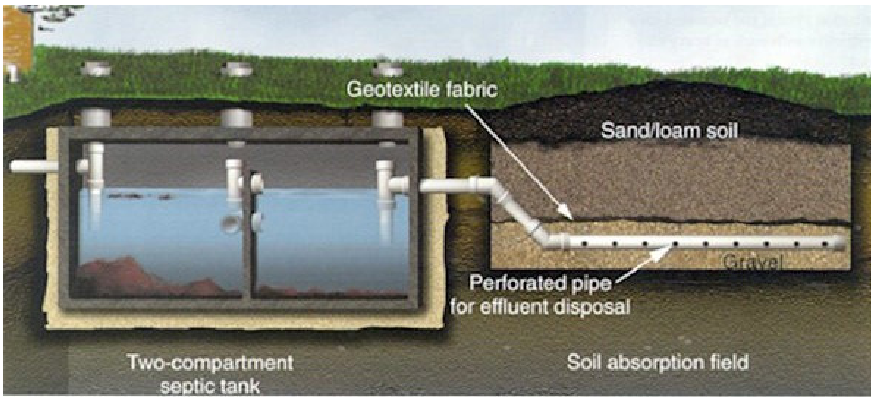
7. Recommendations

Poor wastewater and faecal sludge management continues to pose major health, environmental and socioeconomic risks and costs to the people of Africa. The situation is exacerbated by population growth, which increases the generation of wastewater and faecal sludge in urban areas, causing health, environmental and socioeconomic problems that make national and SDG sanitation goals all the more difficult to achieve.

Lessons from this review show the need for improvement in faecal sludge management, from containment to disposal and reuse. Good practices that can be adopted in many countries across the continent include not only technological innovation for capture, emptying and treatment of sludge but also a well structured institutional arrangement that considers diverse actors, including marginalized groups. Proper coordination of the roles and responsibilities of these diverse actors is required for effective management. Innovations such as the introduction of digital tools (including GPS tracking of trucks, mapping of operators and operation of call centre services) have proved effective in some countries. Special attention must be paid to improving the performance and sustainability of faecal sludge treatment plants by adopting a circular economy approach and low-cost biological methods for faecal sludge management across the continent. Treatment plants can generate revenue to sustain operations by implementing appropriate business models in collaboration with the private sector, which can add value to the by-products generated. These businesses include converting faecal sludge into compost or biochar for use as fertilizer, making it into briquettes as a fuel source for industries, using biogas for electricity generation and using it as feed for fish production.

Significant improvement in sanitation to achieve the related SDG targets will require more investment in faecal sludge management. A World Bank study noted that the capital investments required to achieve the SDGs related to water supply, sanitation and hygiene (targets 6.1 and 6.2) amount to about three times the current investment levels and include an annual cost of USD 9.2 billion for safe faecal sludge management in sub-Saharan Africa (Hutton and Varughese, 2016). Mechanisms must be created to direct investments to poor households with limited access to sanitation facilities. In addition, authorities will need to address the various bottlenecks and inefficiencies in planning and coordination of service delivery along the faecal sludge management chain.

Annex 1: Containment systems and mechanical emptying methods

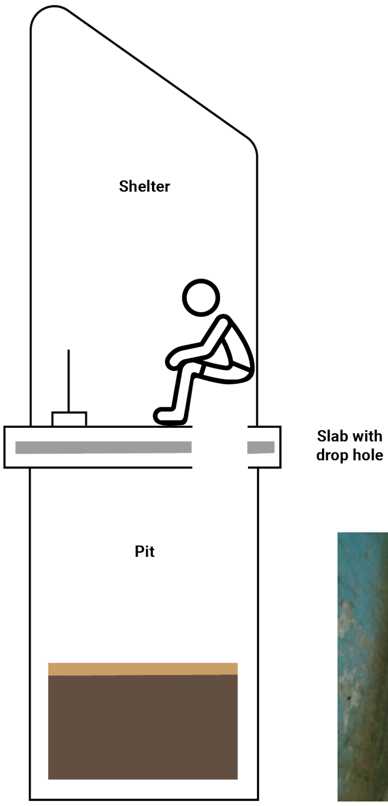


A1:

Typical septic tank

A2:

Rings for septic tank. Source: Sharada Prasad



A3:

Well constructed pit latrine

A4:

Pit toilet: Source: SuSanA Secretariat

A5:

Vacu-Tug: designed to empty latrine pits where there is not enough space for a vacuum tanker. Source: UN HABITAT (https://mirror.unhabitat.org/content.asp?cid=5775&catid=548&typeid=6)

A6:

Trash pump (https://www.sustainablesupply.com/honda-engine-driven-trash-pump-163-cc-wt20xk4ac-c1741947)

A7:

Vacuum trucks
Source: IWMI

A8:

Pit screw auger in South Africa. Photo credit: David M. Robbins in Methods and Means for Collection and Transport of Faecal Sludge, Mikhael *et al.*, 2014

A9:

Most sanitation workers, vacuum truck drivers (A9) and pit emptiers (A10) do not wear protective clothing while working with faecal sludge. Photo credit: IWMI, 2017.

A10:

Most sanitation workers, vacuum truck drivers (A9) and pit emptiers (A10) do not wear protective clothing while working with faecal sludge. Photo credit: Sharada, Prasad.

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