TANZANIA

Faecal Sludge Management (FSM)

Guide for Dar es Salaam

Second Edition

May 2021

Figure 1 Dar es Salaam aerial view

Faecal Sludge Management (FSM)

Guide for Dar es Salaam

Second Edition

This guide was developed based on the outcomes of the "Faecal Sludge Management (FSM) Capacity Development for Dar es Salaam" project conducted in 2019 (financed by New Venture Fund) and the "DEWATS for Dar es Salaam" project implemented from 2016 to 2020 (funded by UK-Aid through the Human Development Innovation Fund (HDIF), and the German Federal Ministry of Economic Cooperation and Development (BMZ)). The guide is intended to serve as an introduction to FSM for practitioners and decision makers who are working on creating an enabling environment for scaling up FSM in Dar es Salaam.

The guide provides an overview of the current situation, the major challenges, and the specific sustainable FSM approaches, all customised to the Dar es Salaam context. The guide focuses on the key challenges of stakeholder engagement, financial arrangements, standards for effluent and by-products, and optimised technical solutions along the entire FSM value chain. The guide is based on the outputs of several workshops and working group meetings, on key literature and on BORDA's field experience.

In 2020 the guide was reviewed and this second edition was developed.

How to use the guide

As mentioned above, the guide is partly based on the output of working groups, workshops and other sector meetings. This is valuable information. Nevertheless, this information is to be used with careful consideration as it might represent the experiences and opinions of specific stakeholders, rather than the broad consensus. For this reason, the guide always indicates the sections based on this type of information.

This icon indicates the parts of the guide that were based on the outcomes of the working groups.

As the scope of the guide is to introduce its readers to "FSM in DAR", the content was reduced to the most relevant information. In addition, the guide avoids repeating information which is provided in detail in other widely recognised publications. For obtaining detailed guidance on FSM, readers are encouraged to refer to the key literature listed in the yellow boxes of the respective chapters.

For further reading, find additional information and links to key supporting literature and detailed guidance on FSM in these yellow boxes.

Figure 2 Small-scale emptying services with eVac and motorised tricycle

Foreword

A safely managed sanitation chain is essential for protecting the health of individuals, communities and the environment. Leaking latrines and raw wastewater can spread disease and provide a breeding ground for mosquitoes, as well as pollute groundwater and surface water that serves as potential sources of drinking water.

Sustainable Development Goal six (SDG 6) aims to ensure availability and sustainable management of water and sanitation for all – by 2030. In particular, target 6.2, aims to achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations. Likewise, target 6.3 seeks to halve the proportion of untreated wastewater discharged into our water.

Indicator 6.3.1 tracks the percentage of wastewater flows from households, services and industrial premises that are treated in compliance with national or local standards. The household component includes both sewage and faecal sludge (FS), treated on-site and off-site, and is monitored as part of the sanitary chain with direct links to indicator 6.2.1 on access to sustainably managed sanitation services.

The “National Water Policy” (NAWAPO) reviewed in 2020 recognises the need of reliable, affordable and sustainable non-sewered sanitation services in Tanzania. In support to this, the “Guidelines for on-site sanitation and faecal sludge management for regulated water and sanitation utilities” by the Energy and Water Utilities Regulatory Authority (EWURA) provides general guidance on the national level. To complement the existing policies and guidelines, an additional guide was developed: the “Faceal Sludge Management (FSM) Guide for Dar es Salaam”. This guide focuses on the specific context of FSM in Dar es Salaam and its key stakeholders as specified, among others, in the Water Supply and Sanitation Act of 2019.

Providing improved sanitation services to all citizens is one of the biggest challenges in Dar es Salaam, particularly the overwhelming task of managing the wastewater and FS generated by over 6.6 million people. Estimates suggest that more than 90% of the population use on-site sanitation facilities, such as pit-latrines and septic tanks. These stand-alone facilities frequently face ongoing challenges relating to safe and affordable emptying, transportation and treatment.

An additional challenge lies in the fact that over 70% of the city consists of high-density, unplanned settlements, where roads are often too narrow for conventional vacuum trucks to access. This means that those households located in inaccessible areas, are left with unsafe options for emptying their containment facilities

In Dar es Salaam, innovative decentralised solutions have been piloted and replicated since 2012. Currently the Dar es Salaam Water Supply and Sanitation Authority (DAWASA) is in the process of scaling up FSM to a citywide level. This guide will contribute to an enabling environment for FSM in Dar es Salaam by creating a general understanding of the major topics related to sustainable FSM.

The guide is consistent with the Government of Tanzania standards and policy framework in water supply, sanitation and hygiene (WASH). The guide supports the Government's efforts to accelerate the achievement of national targets on WASH and those in SDG 6. It is our hope that various stakeholders, including communities and private sector, will use this guide in developing FSM programs in their efforts to contribute to the achievement of WASH services for all.

Eng. Cyprian Luhemeja

CEO – DAWASA

Acknowledgements

The development of this guide was supported by the New Venture Fund (NVF), the German Federal Ministry for Economic Cooperation and Development (BMZ), UK-AID “Human Development Innovation Fund” (HDIF), and the HafenCity University (HCU) of Hamburg. This guide was prepared by the Bremen Overseas Research and Development Association (BORDA) Tanzania, with substantial inputs gathered during regular stakeholder workshops and working group meetings conducted between March and August 2019, and it was peer reviewed by esteemed experts from the Tanzanian water, sanitation and hygiene (WASH) sector in 2020.

The BORDA team are (in alphabetical order): Laura Bright-Davies, Jutta Camargo, Leonidas Deogratius Bernado, Tim Fettback, Evelyn Herrera Lopera, Oscar Mbekenga, Anodi Mdindikasi, Joyce Musira, Godlove Ngoda, Modekai Sanga Andreas Schmidt and Willem van Rheenen.

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Dar es Salaam Regional Administration (RAS – DAR); Dar es Salaam Water and Sanitation Authority (DAWASA); Energy and Water Utilities Regulatory Authority (EWURA); Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC); Ministry of Water (MoW); Municipalities of Ilala, Kigamboni, Kinondoni, Temeke and Ubungo; National Environment Management Council (NEMC); Rural Water Supply and Sanitation Agency (RUWASA); Tanzanian Bureau of Standards (TBS).

We would also like to thank the following institutions who contributed their valuable time to the development of this guide, through attending workshops and working group meetings, providing comments, and carrying out the peer review (in alphabetical order):

Ardhi University; ATAWAS; CCI; GIZ; HDIF; IHI; PDF; Pit Emptier Association; SELF Microfinacnce Fund Ltd.; SNV; TAWASANET; Tujijenge Tanzania Ltd.; UMAWA; University of Dar es Salaam; Wastewater Solutions; WaterAid; Water Institute Dar es Salaam.

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Beda Levira (Ifakara Health Institute)
Charles Makoye (DAWASA)
Martha Kabuzya (ATAWAS)
Peter Hawkins (Senior Sanitation Consultant)

Resources

In order to maintain consistency with existing and commonly referred to sector literature, and to provide comprehensive guidance for the most recommended FSM solutions, content and diagrams within this document have been extracted and adapted from several resources. These are listed in the yellow boxes within the respective chapters. In particular, we would like to highlight the following publications which provided substantial content for this guide:

- Camargo, J., Bright–Davies, L., Fettback, T., Sanga, M., & Wolter, D. (2018). Guidelines for the Application of Small-Scale, Decentralised Wastewater Treatment Systems. MoW. Free PDF available at: www.maji.go.tz/pages/guidelines
- Parkinson, J., Lüthi, C. & Walther, D. (2014). Sanitation 21 - A Planning Framework for Improving City-wide Sanitation Services. Fee PDF available at: www.iwa-network.org/publications/sanitation-21-a-planning-framework-for-improving-city-wide-sanitation-services/
- Strande, L., Ronteltap, M., & Brdjanovic, D. (Eds.) (2014). Faecal Sludge Management: Systems Approach for Implementation and Operation. IWA. Free PDF available at: www.sandec.ch/fsm_book
- Tayler, K. (2018). Faecal Sludge and Septage Treatment: A guide for low- and middle-income countries. Free PDF available at: www.susana.org/_resources/documents/default/3-3439-7-1540380071.pdf
- Tilley, E., Ulrich, L., Christoph, L., Reymond, P., Schertenleib, R., & Zurbrügg, C. (2014). Compendium of Sanitation Systems and Technologies. IWA; EAWAG; WSSCC. Free PDF available at: www.sandec.ch/compendium
- World Health Organization (2018). Guidelines on sanitation and health. Free PDF available at: www.who.int/water_sanitation_health/publications/guidelines-on-sanitation-and-health/en/

Content relevant to the local Tanzanian context was extracted from these resources.

Readers are encouraged to refer to the original documents, to gain more insight into potential options.

Acronyms & Key Terms

ABR	Anaerobic Baffled Reactor
AF	Anaerobic Fiilter
BOD	Biochemical Oxygen Demand
BORDA	Bremen Overseas Research and Development Association
CAPEX	Capital Expenditure
COD	Chemical Oxygen Demand
DAWASA	Dar es Salaam Water and Sanitation Authority
DAWASCO	Dar es Salaam Water and Sewerage Corporation
DEWATS	Decentralised Wastewater Treatment Solutions
DAR	Dar es Salaam
E&T	Emptying and Transportation
EWURA	Energy and Water Utilities Regulatory Authority
FC	Faecal Coliforms
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
IHI	Ifakara Health Institute
LGA	Local Government Authorities
MoHCDGEC	Ministry of Health, Community Development, Gender, Elderly and Children
MOW	Ministry of Water
NEMC	National Environment Management Council
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PGF	Planted Gravel Filter
PPE	Personal Protective Equipment
PPP	Public-Private Partnership
SFD	Shit Flow Diagram
SME	Small and Medium Enterprises
TBS	Tanzania Bureau of Standards
TSS	Total Suspended Solids
TZS	Tanzanian Shillings
VIP	Ventilated Improved Pit
WHO	World Health Organization
WTP	Wllingness To Pay
WSP	Waste Stabilisation Pond
WSSA	Water Supply and Sanitation Authorities

Excreta	Collective term used for human wastes, consisting of faeces (wet solids with a high organic content) and liquid urine. Excreta is small in volume, but concentrated in both nutrients and pathogens.
Faecal sludge	General term for undigested or partially digested slurry or solids resulting from storage or treatment of blackwater or excreta. This is a mixture of human water and solid wastes (e.g. toilet paper or other anal cleansing materials, menstrual hygiene materials) that are disposed in pits, tanks or vaults of on-site sanitation systems. In this guide no differentiation is made between faecal sludge (FS) and septage. In general, septage comprises FS, the supernatant water that accumulates above it, and material that is lighter than water that forms a scum layer on the liquid surface.
Wastewater	Any water that has been polluted by human use and is transported via sewer. It can be categorised as: ▶ Domestic wastewater consisting of blackwater (excreta, flush water and anal cleansing water/ material) and greywater (kitchen and bathing wastewater) ▶ Institutional wastewater (e.g. from hospitals and schools) is produced in a high volume at one site and under one management entity, and has characteristics similar to domestic wastewater ▶ Industrial wastewater (e.g. from SMEs or large industrial operations) has a high variation of wastewater characteristics depending on the industrial processes that generate it ▶ Agricultural, horticultural and aquaculture effluent

Figure 3 Discharging FS at Miburani-Temeke FSTP, Dar es Salaam

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1. INTRODUCTION

1.1 Current situation in Dar es Salaam

Dar es Salaam is a complex city. It is characterised by a high variety of urban structures. A broad spectrum of formal to informal settlements exists, with various levels of planning. Also, other critical parameters such as infrastructure development, level of income and population density are highly variable across the city. The city of Dar es Salaam is located on the Indian Ocean. It is one of the 31 administrative regions in Tanzania consisting of five municipalities: Kinondoni, Ilala, Ubungo, Temeke and Kigamboni. It is the largest city and the economic hub of Tanzania. Its estimated population is 6.7 Million people (2020). Dar es Salaam is considered to be one of the fastest growing cities in the world, with an annual growth rate of 5.6%. In addition, the population on work days increases significantly as workers from surrounding towns travel to the city.

Population growth in Dar es Salaam has resulted in urban spatial expansion, the bulk of which has happened in the form of informal settlements, often with little infrastructure in place. More than 70% of the population lives in informal settlements. In these areas, income levels are diverse; low, middle and high-income households are found in informal settlements. Dar es Salaam's population density is app. 3,200 people/km^2, ranging from 46 to 46,721 people/km^2. The peri-urban outskirts of Dar es Salaam have rural characteristics. Water supply coverage is 75%. During the two rainy periods each year, on-site sanitation technologies are affected by flooding due to the rising groundwater level.

These conditions impose large challenges for safe FSM. Nevertheless, Tanzania's National Water Sector Development Strategy 2006-2015 describes access to safe and hygienic methods of excreta disposal as a basic need and right for all human beings.

A shit flow diagram (SFD) can be used to visualise the approximate quantities of FS and their corresponding pathways. In 2015 a SFD was developed for Dar es Salaam, as seen in Figure 5 on the next page. The SFD shows that half of the total excreta generated in Dar es Salaam is not safely contained on-site. This is due, for example, to partially lined pits and soak pits in areas with high groundwater levels. 40% of the generated excreta is safely contained on-site. The remaining 10% of excreta flows are 1% open defecation and 9% wastewater systems (sewerage). Only 11% of the generated excreta is delivered as FS to treatment sites, and 4% of the generated excreta is conveyed by sewer systems to treatment facilities. Thus, in total 15% of generated excreta is delivered to treatment sites, and it is assumed that out of this only 50% is treated. More details on the current FSM situation in Dar es Salaam (along the FSM value chain) are provided in Table 3 below.

Detailed information on the current Dar es Salaam context for FSM is provided in several reports and in publications, such as:

- Assad et. al (2018). Performance Audit Report on Provision of Sewage Services in Urban Areas. EWURA
- Brandes et. al (2015). Shit Flow Diagram (SFD) Report for Dar es Salaam. Dar es Salaam, Tanzania.
- DAWASA (2017). Feasibility Study for septic tank sewerage treatment facilities in areas with no sewer and with poor sanitation in Dar es Salaam.
- Jenkins et al. (2015). Pit Latrine Emptying Behavior and Demand for Sanitation Services in Dar Es Salaam, Tanzania.

Figure 4 <Small-scale pit emptying service using a gulper

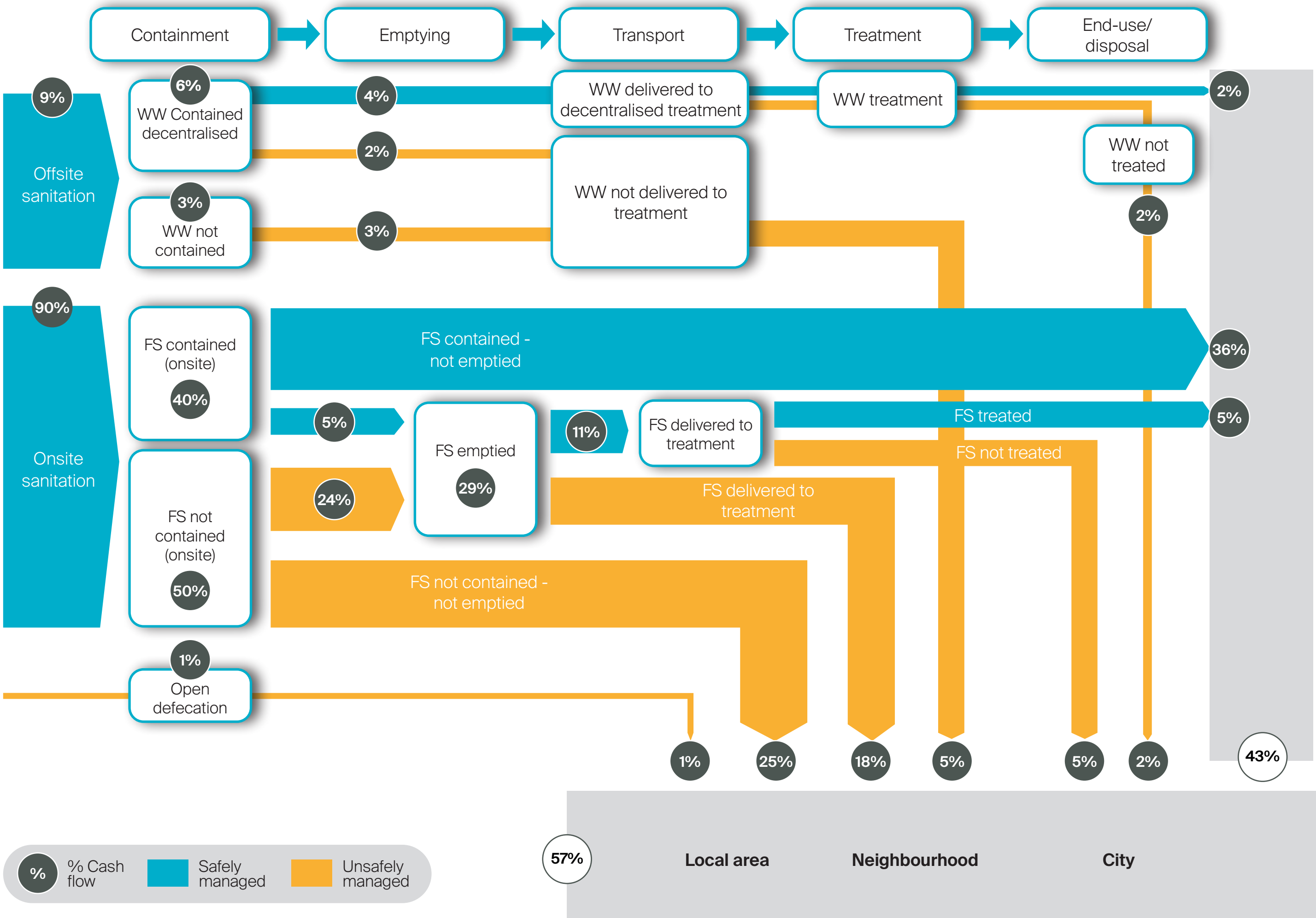


Figure 5 Shit Flow Diagram (SFD) for Dar es Salaam (Eawag-Sandec, 2015)

1.1.1 Faecal Sludge Treatment Plants in Dar es Salaam

Currently, Dar es Salaam has a limited number of treatment sites that officially allow the discharge of FS. There are nine existing water stabilisation ponds (WSPs): Vingunguti, Kurasini, Mikocheni, Lugalo, University, Mabibo, Buguruni, Ukonga, and one at the Airwing. Of these only two receive FS: Vingunguti and Kurasini. These ponds have been underperforming since their design capacities are no longer able to cater to the current population's demands. The level of maintenance for the WSPs is very low, which leads to poor performance of the facilities. Predominantly these ponds were designed to treat wastewater, but now exist as co-treatment facilities for both FS and wastewater (as shown in Table 1).

Location of WSP	WSP system	Amount FS received, [m^3/day]
Vingunguti	6 cells (both anaerobic to maturation)	1,900
Kurasini	5 cells (both anaerobic to maturation)	430

Table 1 WSPs in Dar es Salaam which currently receive FS (DAWASA, 2017)

Figure 6 WSP for wastewater treatment in Dar es Salaam

In addition to two centralised WSPs, five decentralised Faecal Sludge Treatment Plants (FSTPs) have been implemented. These systems were implemented as pilot plants to test and demonstrate decentralised FSM. Table 2 provides an overview of the current (2020) status of these FSTPs.

FSTP location	Capacity	Beneficiaries	Status	Year of inauguration
Tungi-Kigamboni	$5m^3/d$	max. 15,000	Operational	2014
Mlalakuwa-Kinondoni	$5m^3/d$	max. 15,000	Operational	2015
Mburahati-Ubungo	$10m^3/d$	max. 30,000	Operational	2018
Miburani-Temeke	$10m^3/d$	max. 30,000	Operational	2018
Temeke-Tuangoma	$10m^3/d$	max. 30,000	Operational	2019

Table 2 Small-scale decentralised FSTPs in Dar es Salaam (2020)

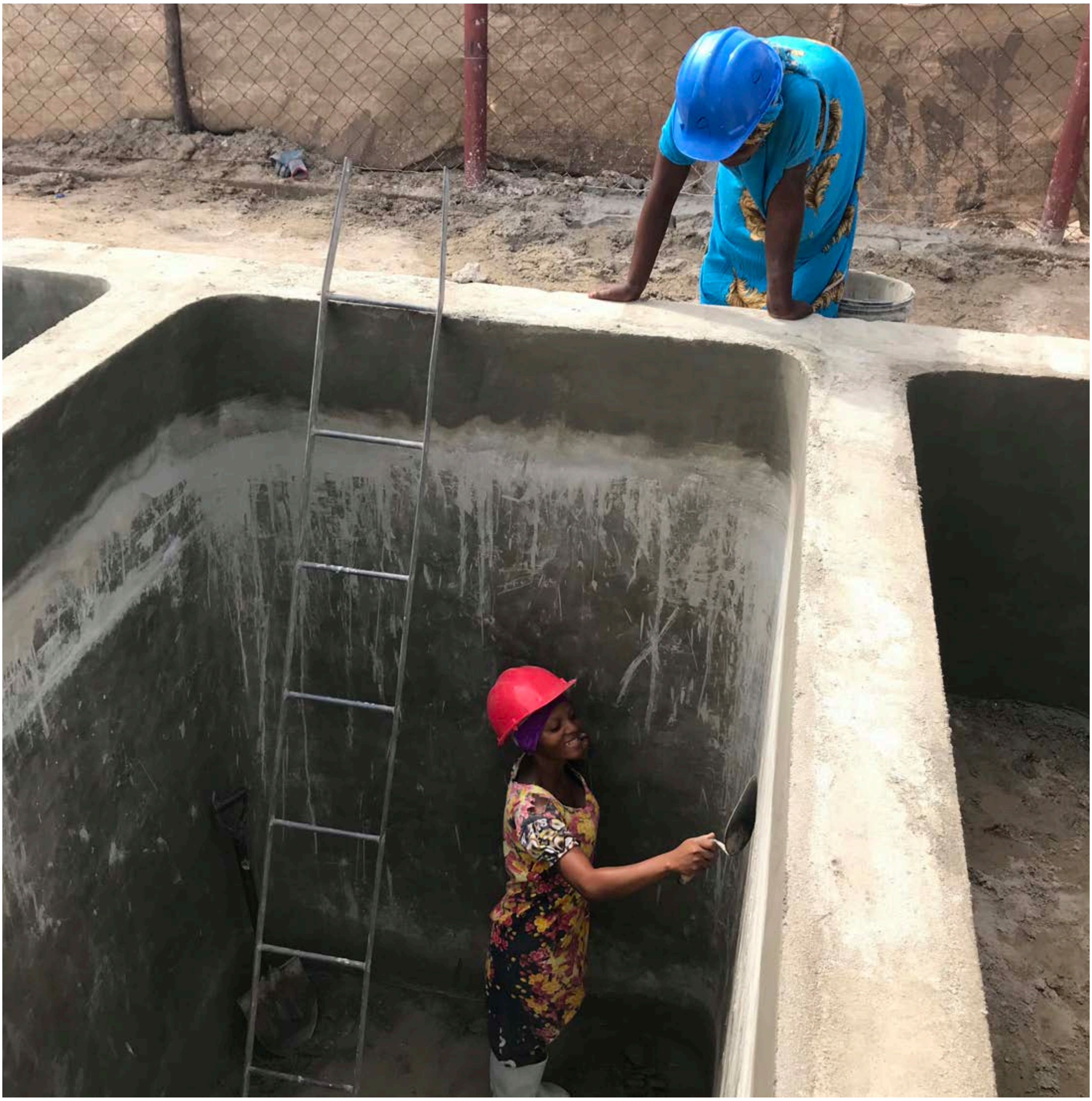


Figure 7 Construction of Anaerobic Baffled Reactor (ABR) and Anaerobic Filter (AF) at Mburahati-Ubungo FSTP

1.1.2 FSM value chain in Dar es Salaam

The FSM value chain consists of the horizontal interlinkages between various components of excreta management systems which include containment, emptying, transportation, treatment and reuse or disposal. It shall be noted that the supernatant from on-site sanitation systems and/or the liquid which percolates into the ground from non-watertight structures is not considerd in this value chain analysis. Table 3 provides an overview of the current FSM value chain in Dar es Salaam.

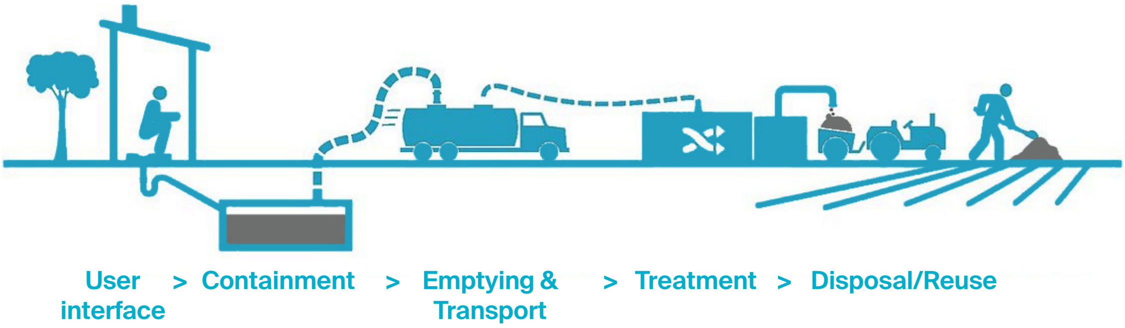
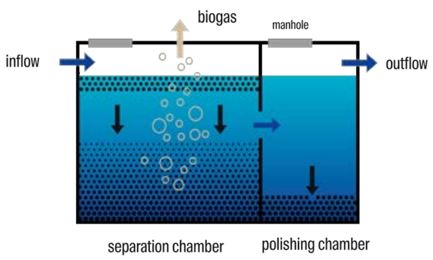


Figure 8 FSM value chain

	User Interface
	Based on the SFD and as per a study conducted by BICO (DAWASA, 2017) about 12,000m^3 to 21,000m^3 of FS is generated in Dar es Salaam per day. Predominant systems at the user interface are direct drop (58%), pour flush (34%) and full flush (6%) toilets.
	Containments
	The main onsite sanitation systems (OSS) used in Dar es Salaam are pit latrines (mainly ventilated improved pit latrines) (58 - 75%) and septic tanks (15 - 41%). A small number (app. 10%) of urban dwellers are connected to DAWASA's sewer network. The remaining app. 1 - 2% practice open defecation. The sewer network covers central areas of the city and has only small sections outside of the centre. Septic tanks are utilised by the middle- to high-income population. Pit latrines are predominantly semi-lined and partly raised above the ground in areas of high water table. The average pit depth in Dar es Salaam is 3 - 4.5m.
	Emptying and Transport
	In Dar es Salaam, formal emptying and transportation (E&T) services apply vacuum trucks, or mud pump and gulper technologies combined with motorised tricycles. Around 120 vacuum trucks with an average of 7.4m^3 capacity are operating. Vacuum truck service providers do 2 to 3 trips on average per day: during the rainy season 3 to 4, and during the dry season 1 to 2. Hereby 1,800m^3 to 2,700m^3 of FS is collected per day. 60% of the containment systems emptied are residential and the remaining 40% are at institutions, small and medium enterprises (SME) or industries. "Gulper", trash pumps, mud pumps and eVac are applied to empty the pits in inaccessible areas. The FS is then transported on motorised tricycles (up to 1m^3 per trip) to the FSTP. Illegal methods include pit diversion (or flooding out), which mostly happen during heavy rainfall. Hereby FS is diverted and flooded out by stormwater. Another illegal method of emptying is the manual emptying by so called "frogmen" (Vyura) who climb into the pits and empty the contents using buckets. Later the FS gets buried into another dug hole close to the pit or discharged to the nearest open drain or water body. Flooding out or pit diversion is the most frequently observed emptying service, followed by vacuum truck services.

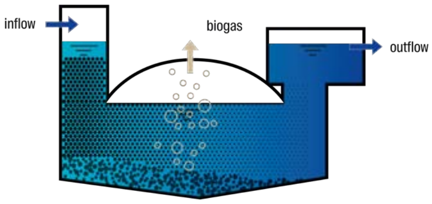
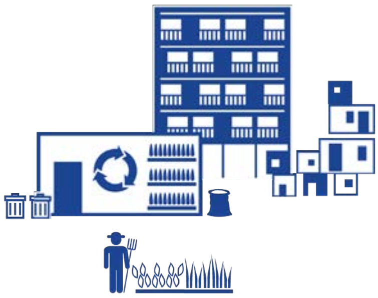
	Treatment
	Existing WSPs in Dar es Salaam built before 1990 were not designed for FS treatment and receive infrequent maintenance. A total of nine WSPs exist in the city, most of which are managed by DAWASA. FS collected by vacuum trucks or gulper groups is also delivered to the WSPs. EWURA reports that the average FS volumes disposed at the two WSPs, Vingunguti and Kurasini, are 2,000m^3/day and 135m^3/day, respectively. In addition to these, 5 small-scale FSTPs have been implemented which receive a total of 40m^3/day of FS in Kinondoni, Ubungo, Kigamboni and Temeke.
	Disposal/Reuse
	After partial treatment at the WSPs, the effluent is discharged to rivers and conveyed to the ocean, while some wastewater is directly disposed in the ocean through the sea outfall without any treatment. The decentralised FSM approach advocates for the implementation of systems with a potential for by-product reuse. Generally, decentralised FSTPs do not discharge to surface water bodies. Rather, these (usually) small-scale FSTPs enable the reuse of by-products such as biogas, stabilised sludge as soil conditioner, and treated effluent for watering banana plantations or landscape irrigation.

Table 3 Current Dar es Salaam context along the FSM value chain

Figure 9 Small-scale E&T equipment: eVac and motorised tricycle at Mburahati-Ubungo FSTP

1.2 Faecal Sludge Management

1.2.1 Why FSM?

The overall objective of FSM is to ensure that the FS removed from on-site and decentralised sanitation facilities is dealt with in a way that protects both public health and the environment and does not create a local nuisance. FSM is a holistic approach recognising the urban water cycle and urban environmental sanitation (see Figure 10).

▶ Public health concerns

Faeces contains microorganisms which can be dangerous, especially if the person who excreted the faeces is infected. The microorganisms that cause diseases are referred to as pathogens. From a public health perspective, the main aim of FSM is to prevent the public from coming into contact with these pathogens. Thus, first the FS shall be contained safely and infiltration into the ground shall be avoided, in order to protect groundwater sources. Desludging the containment system involves health risks for the pit emptiers, if direct contact with the FS is not controlled. Also, if untreated FS is dumped after emptying into the environment, the health risk is high.

▶ Environmental protection concerns

Faeces consists largely of water and organic compounds. In the presence of bacteria, the latter breaks down into simpler components, using oxygen available in the environment. For faecal material discharged to a watercourse, this oxygen is available in the receiving water but the high oxygen demand for biological degradation will quickly reduce the oxygen content of the water. In addition, the nutrients present in the FS lead to increased plant growth in the watercourses, and thus to a further increase in organic substances, which when decaying further reduces the available oxygen in the watercourse. This leads to anaerobic conditions and destruction of aquatic organisms (eutrophication).

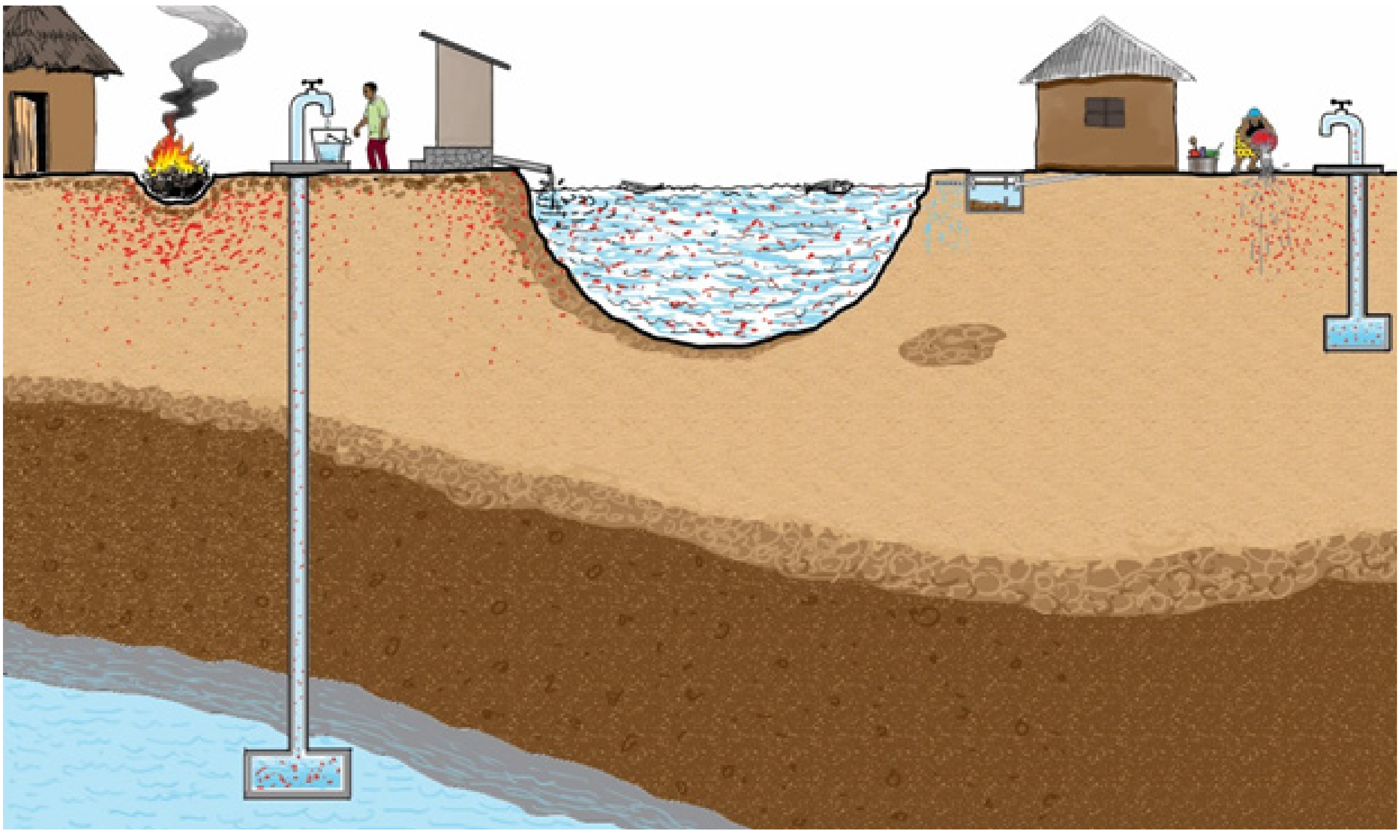


Figure 10 Urban water cycle and sanitation objectives

1.2.2 Global Status of FSM

The number of people living in cities is projected to increase by 50% from 4 to 6 billion between 2016 and 2045. Much of this growth is occurring in low-income and lower middle-income countries. OSS currently serves more than 2.7 billion people globally and this number is expected to be as high as 4.9 billion by 2030.

As a solution, decentralised sanitation systems have gained attention over the last years as an alternative to complement conventional centralised systems. The concept of decentralised sanitation supports stepwise (incremental) implementation, which acknowledges planning within the context of available resources, and thus is more sustainable. Decentralised systems are considered economically and ecologically sustainable, socially accepted, and as systems which allow resource recovery and reuse, therefore addressing one of the key points towards achieving the 2030 Agenda for Sustainable Development.

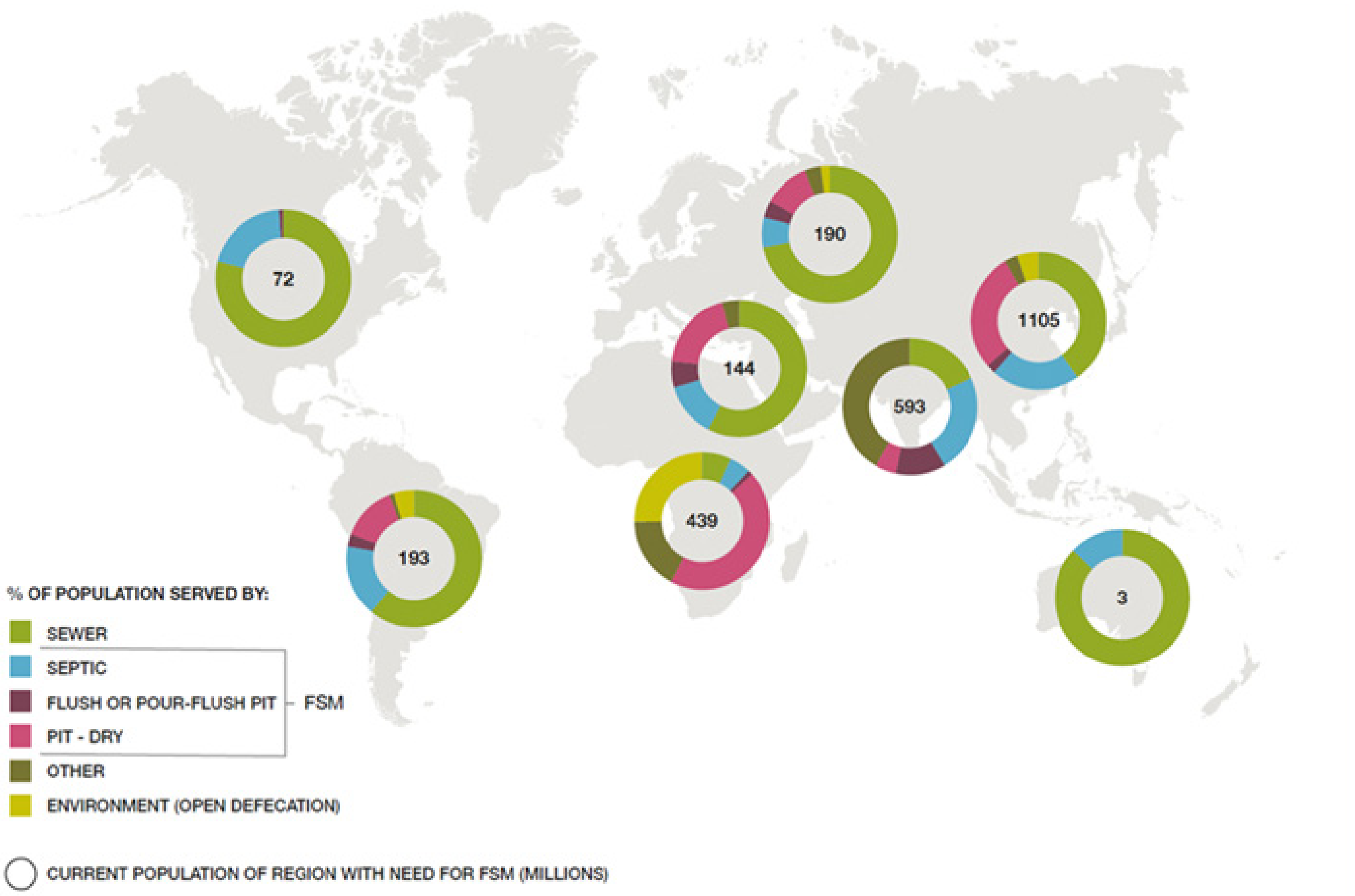


Figure 11 Current coverage of sanitation systems (Rao et al. 2016)

1.2.3 FSM enabling environment

An enabling environment is a set of interrelated conditions that empower development actors to engage in development policies, strategies and projects in a sustained and effective manner. This includes political, legal, institutional, financial, economic, educational, technical and social aspects. An enabling environment is important for the success of any development investment; without it, the resources committed to bringing about change will be ineffectively used. The six key elements of an enabling environment are:

- The level of government support, in terms of political support and favourable national policies and strategies
- The legal and regulatory framework, with appropriate standards and codes at national and municipal levels
- The institutional arrangements that support efficient collaboration and engagement of all relevant stakeholders
- Effective skills and capacity ensuring that all participants understand and accept the tools and concepts, and are able to apply and implement them
- The financial arrangements that facilitate the mobilisation of funds for implementation and O&M
- The socio-cultural acceptance, i.e. matching service provision to the users' perceptions, preferences, and commitments to both short-term and long-term participation

Within this guide, it is important to emphasise that the success of FSM systems depends on a vast array of variables, which are not limited to the technical implementation of the system. If any of the named key elements of the enabling environment are not sufficiently considered, the system is very likely to fail.

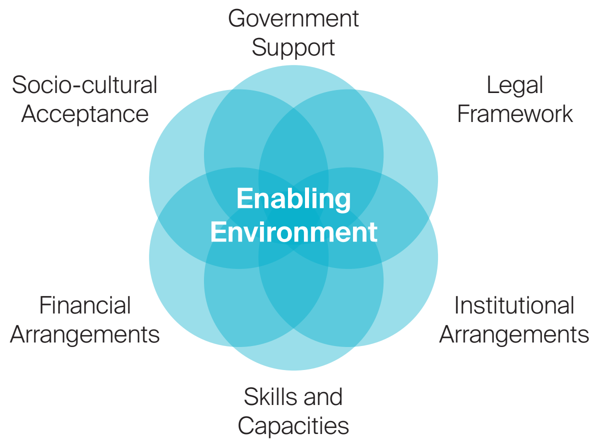


Figure 12 Enabling environment for environmental sanitation (Lüthi, et al., 2011)

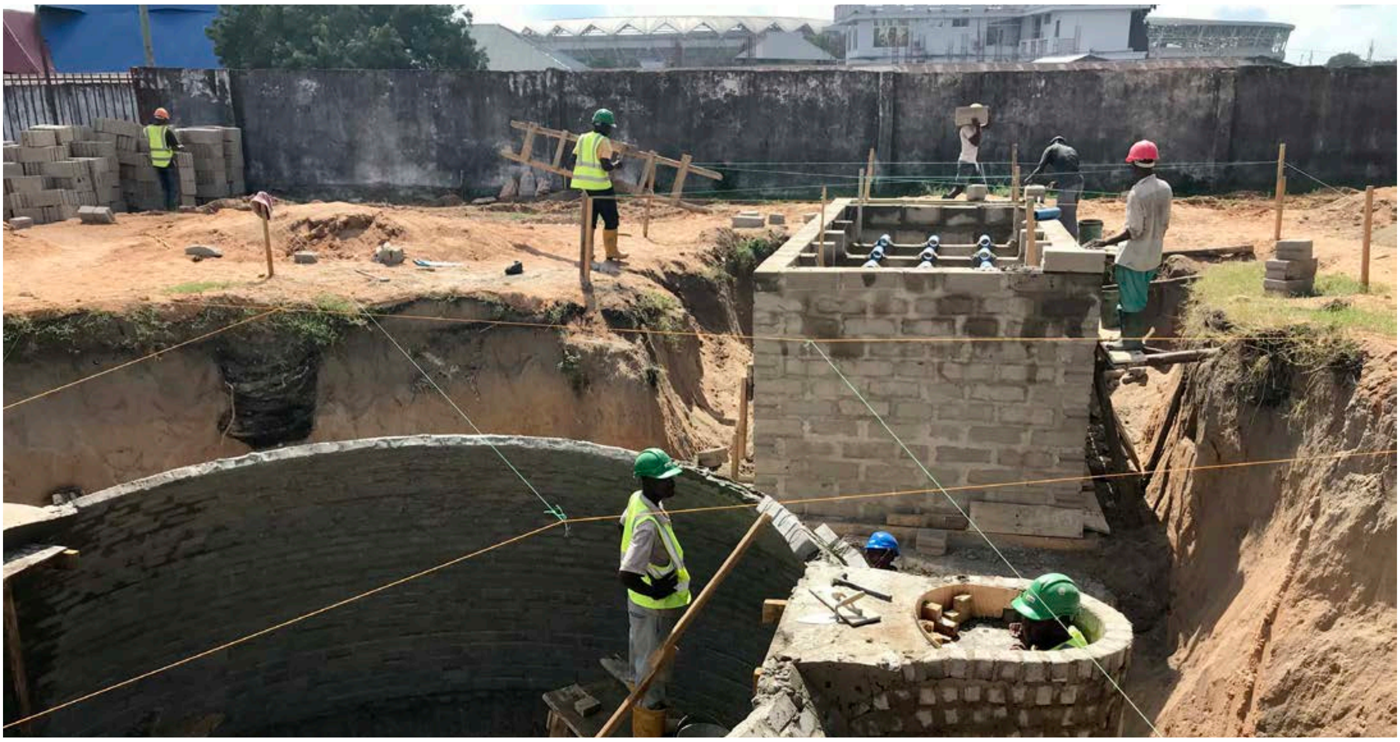


Figure 13 Construction of biogas settler, ABR and AF at an FSTP in Miburani-Temeke

Figure 14 Planned area in Dar es Salaam, accessible by vacuum truck

Figure 15 Unplanned area in Dar es Salaam, inaccessible by vacuum truck, partially accessible by motorised tricycle

1.2.4 FSM centralised and decentralised

Decentralised sanitation systems, in comparison to centralised systems, are located at or near the point of FS generation. Decentralised systems can be characterised and differentiated from centralised systems along the following lines:

- Volume
Decentralised systems generally treat relatively small volumes of FS.
- Treatment technology
Large-scale centralised systems in low-income countries are typically WSPs. These are open systems which bear the risk of nuisance to neighbouring communities. Alternative large-scale technologies often require a higher level of mechanisation, compared to small-scale decentralised systems. In general, decentralised FSTPs need to be integrated into the urban environment, and therefore require technologies with a low negative impact on their surroundings.
- Relative scale
Centralised systems are intended to serve entire towns or substantial areas of large communities. Decentralised systems serve only a portion of a community.

Decentralised systems are particularly suitable for urban and peri-urban areas such as informal settlements that are not connected to centralised sewerage infrastructure. Small-scale systems are also suitable in small to medium-size towns that do not have centralised infrastructure in place. A challenge of decentralised systems is the higher effort for monitoring a larger number of systems.

Strengths of decentralised FS treatment systems

- Shorter distances for FS transportation
Shorter distances between the point of FS generation and treatment reduce costs, as fuel for transporting vehicles and time in traffic are reduced.
- Enabling stepwise implementation
As the availability of financial resources for system upgrades is often the limiting factor, incremental improvement presents a more pragmatic approach.
- Can operate with zero or minimal electrical energy
Small-scale decentralised FSTPs can apply technologies with minimal mechanical equipment and thus are not dependent on electrical energy.
- Increased potential for resource reuse
The possibility for reuse (e.g. in landscaping) is higher, because the effluent can be used at multiple locations, homogeneously spread in the town or city.
- Reducing the risk of system failure
Easy financial planning and lower requirements for O&M compared to centralised systems serve to reduce the risk of system failure In addition if a high number of FSTPs are implemented the challenges resulting from failure of a single FSTP is relatively low compared to the failure of a single centralised FSTP (robust systems).
- Low overall impact of (temporary) failure of an individual FSTP
This is compared to failure of a centralised system, which can lead to major financial, environmental and public health impacts.

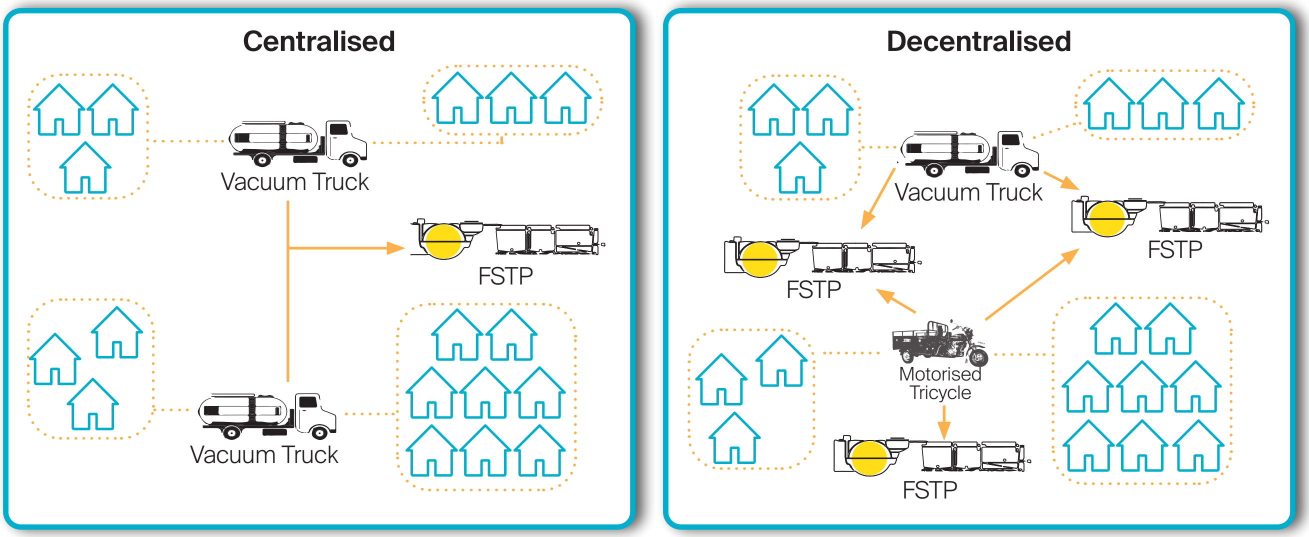


Figure 16 Centralised and decentralised FSM

1.2.5 Small and large-scale systems

A small-scale FSTP refers to a plant that treats a relatively small volume of FS per day. The exact volume needs to be defined, but can be assumed to be smaller than 20m^3 per day. Treatment capacities of FSTPs can vary widely. The optimal treatment capacity needs to be identified during planning and design of the system according to its specific context. Larger systems require more detailed specifications, such as on energy for pumping. Additionally, larger systems are required to meet stringent effluent standards due to the increased volume and load of contaminants being emitted from the system.

E&T equipment can also be categorised into small and large-scale equipment. Within this guide vacuum trucks are referred to as medium or large-scale E&T equipment, smaller systems (e.g. motorised tricycles) are referred to as small-scale.

1.2.6 FSM and wastewater management

FSM deals with the processes that enable the containment of human excreta on-site, its emptying and transportation to the treatment site (FSTP), the treatment, and the final discharge or reuse. Wastewater management refers to the processes which are related to handling polluted water (e.g. due to excreta or industrial processes) which is conveyed by sewer systems to the treatment site (WWTP).

Many FS treatment technologies are based on those developed for wastewater treatment, but it is important to note that these technologies cannot be directly transferred. FS mainly consists of excreta (a high concentration of pollutants) and thus its characteristics differ from wastewater (which is characterised by its high water content). This has a direct impact on the efficiency of treatment mechanisms. In comparison to wastewater, FS typically has a higher solids content and a higher concentration of pollutants, pathogens and inorganic substances. Besides this, FS characteristics differ widely between different on-site sanitation technologies and system management types. The quantity and characteristics of FS also depend on the design and construction of the user interface (toilet type), how the technology is used, how the FS is collected, and the frequency of collection.

For example, the characteristics of FS from a public toilet are substantially different to sludge from a private septic tank. The approximate characteristics of FS (high strength and low strength) and wastewater are listed in Table 4. The collection, treatment and management system needs to be adapted to the specific characteristics of FS or wastewater.

Another fundamental difference between wastewater management and FSM is the need for physical E&T of FS. Typically, a variety of service providers with different technologies and methods for FS E&T can be found operating simultaneously. Improper management of FS leads to a high risk of exposure for service providers to physical, chemical and biological hazards during E&T and discharge of FS. This occurs if the tasks are carried out without suitable equipment, leading to contact between humans and the harmful substances in FS.

Parameter	FS high strength	FS low strength	Municipal wastewater
	E.g. public toilet	E.g. private septic tank	E.g. sewer system
COD [mg/l]	20,000 to 50,000	< 15,000	500 to 2,000
BOD [mg/l]	App. 7,600	840 to 2,600	300 to 500
COD/BOD [-]	5:1	10:1	2:1
NH4-N [mg/l]	2,000 to 5,000	< 1,000	30 to 70
TSS [mg/l]	> 30,000	App. 7,000	200 to 700
Ptotal [mg/l]	450	150	9 to 63
Helm. Eggs [no./l]	20,000 to 60,000	App. 4,000	300 to 2,000
FC [cfu/100ml]	10^{52}	10^{52}	10^4 to 10^{52}

Table 4 Characteristics of FS and wastewater (Strauss & Montangero, 2002; Strande et al., 2014; ATV-DVWK-A 198, 2003)

One significant strength of wastewater systems compared to FS systems is that less untreated wastewater or septage infiltrates the ground on-site. Nevertheless, there is no one solution for all types of urban structures. Wastewater and FS management should be seen as parts of environmental sanitation. Environmental sanitation can be seen as a set of approaches to achieve a sanitary physical environment. Environmental sanitation goes one big step further than the traditional notion of "sanitation" which is limited to the immediate aspects of human excreta and/or the provision of toilets. This approach includes FS and wastewater management, solid waste management, stormwater management and partly also water supply.

1.2.7 Stepwise implementation

The concept of stepwise implementation applies to both the technical implementation of FSM and the implementation of national standards for effluent quality. The concept is based on the idea that small steps of improvement are more feasible compared to a single large step, and eventually these small steps will lead to the same or an even higher level of improvement. This is visualised in Figure 17.

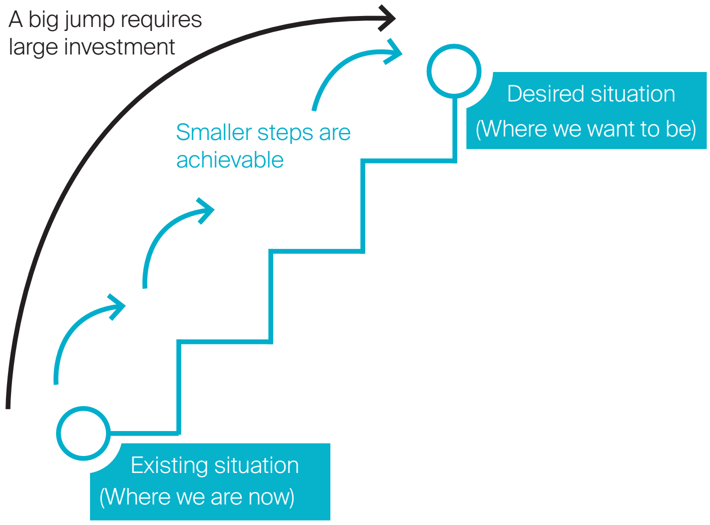


Figure 17 Concept of stepwise implementation (Tayler & Parkinson, 2003)

Strengths of stepwise implementation	
▶ Polluters are more likely to afford gradual investment for control measures	▶ The present value of construction costs is reduced
Polluters and/or water authorities will find it much more feasible to divide investments into different steps, than to make a large and in many cases unaffordable investment.	*The division of construction costs into different stages leads to a lower present value than a single large initial cost. This aspect is more relevant in countries where, due to inflation, interest rates are high.*
▶ The cost-benefit of the first stage is likely to be more favourable than in the subsequent stages	▶ Operators have more time and better conditions to ascertain the particular FS characteristics
In the first stage, when environmental conditions are poor, a large benefit is usually achieved with a comparatively low cost. In the subsequent stages, the size of the benefit is not as substantial, but the associated costs are high. The cost-benefit ratio is then less favourable.	*The operation of the system will involve monitoring, which will enable operators to develop more specialised knowledge of the FS characteristics. The design of the second or subsequent stages will be based on actual characteristics observed during monitoring, and not on generic values taken from the literature.*
▶ There is the opportunity to optimise operation, without necessarily undergoing a physical expansion	▶ There is time and opportunity to implement, in the second stage, new techniques or better-developed processes
Experience in the operation of the system will lead to a good understanding of its behaviour. This will allow, in some cases, the optimisation of the process (improvement of efficiency or capacity) without necessarily requiring the physical expansion of the system. The first stage will be analogous to a pilot plant.	*The availability of new or more efficient processes for FS treatment is always increasing with time. Process development is continuous and fast. The second or subsequent steps can make use of better and/or cheaper technologies, which would not be possible within a single large step.*
▶ The country has more time to develop its own standards	▶ The country has more time and better conditions to develop a suitable regulatory framework and institutional capacity
As time passes, the experience in operating the system and evaluating its positive and negative implications in terms of water quality, health status and environmental conditions will lead to the establishment of standards that are truly appropriate for local conditions.	*Experience obtained in the operation of the system and in setting up the required infrastructure and institutional capacity for regulation and enforcement will improve progressively, as the system expands in the second and subsequent stages.*

Table 5 Strengths of stepwise implementation

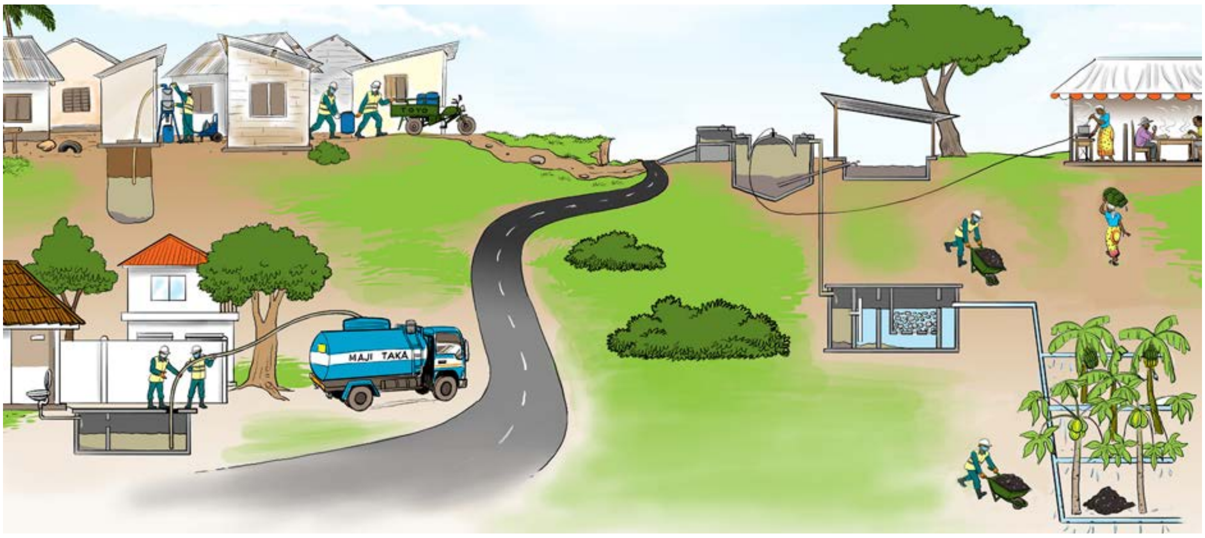


Figure 18 The FSM value chain from containment to reuse for the specific context of Dar es Salaam

1.2.8 Citywide Inclusive Sanitation

The framework of Citywide Inclusive Sanitation (CWIS) declares that adaptive, expandable, decentralised and cost-effective approaches, mixing onsite and sewerage solutions, can be resilient to external economic, demographic and environmental shocks. Furthermore, decentralizing sanitation can intensify local involvement, which allows developing sanitation solutions that reflect local conditions and meet the needs of customers (Citywide Inclusive Sanitation, Call to Action, 2019).

The Manila Principles on CWIS are defined as:

- **Equity**
Everyone in an urban area – including communities marginalised by gender, social, and economic reasons – benefit from equitable, affordable, and safe sanitation services.

- **Environment and public health**
Human waste is safely managed along the entire sanitation service chain, starting from containment to reuse and disposal.

- **Mix of technologies**
A variety of sewered and non-sewered sanitation solutions coexist in the same city, depending on contextual appropriateness and resource recovery potential.

- **Comprehensive planning**
Planning is inclusive and holistic with participation from all stakeholders including users and political actors – with short- and long-term vision and incremental perspective and is synergistic with other urban development goals.

- **Monitoring and accountability**
Authorities operate with a clear, inclusive mandate, performance targets, monitoring requirements, human and financial resources, and accountability.

- **Mix of business models**
Sanitation services are deployed through a range of business models, funding sources, and financial mechanisms to reach all members equitably.

Supporting literature

- Gambrill, M., Gilsdorf, R. J., Kotwal, N. (2020). Citywide Inclusive Sanitation — Business as Unusual: Shifting the Paradigm by Shifting Minds.
- Lüthi, C., Willetts, J., Hoffmann, S. (2020). Editorial: City-Wide Sanitation: The Urban Sustainability Challenge. Retrieved from https://doi.org/10.3389/fenvs.2020.585418.
- Schrecongost, A., Pedi, D., Rosenboom, J.W., Shrestha, R., Ban, R. (2020). Citywide Inclusive Sanitation: A Public Service Approach for Reaching the Urban Sanitation SDGs.

1.2.9 FSM planning framework

The table below indicates the optimised planning structure for FSM.

Standard project phases	Activities	Outcomes
Exploratory study	**A** Preliminary assessment of the initial situation and first inventory of stakeholders	Overview of the situation; facilitators are identified
▶ Inception report		
Preliminary (pre-feasibility) studies	**B** Identification and preliminary characterisation of the stakeholders and their relationships	All stakeholders are identified and characterised
	C Initial launching workshop, including field visit with all the stakeholders	Stakeholders are sensitised to sanitation reality and aware of the project's objectives
	D Assessment of: ▶ Sanitation practice and needs, reuse interests ▶ Institutional setup, government support ▶ Legal and regulatory framework ▶ Existing organisational modes ▶ City structure and heterogeneity of sanitation practices ▶ Existing financial flows ▶ Climate	Sanitation practices are identified, as well as urban heterogeneity; strengths, weaknesses, opportunities and threats are identified (SWOT analysis); the enabling environment is described
	E Selection of potential organisational modes	Orientation of the process towards realistic options
	F Identification of sites for treatment	Stakeholders have indicated existing and potential sites
	G Characterisation and selection of key stakeholders	Stakeholders who have interest in and/or influence on the process are identified
▶ Preliminary studies report		
Feasibility study	**H** Quantification and characterisation of sludge	Process leaders know what has to be treated
	I Characterisation and selection of sites	Appropriate sites are selected
	J Preselection of combinations of technologies, organisational modes and financial mechanisms	Scenarios are elaborated
	K Detailed evaluation of selected options, including: ▶ Requirements of technology combinations, pros and cons, O&M ▶ Organisational mode and institutional setup, roles & responsibilities, contractual arrangements ▶ Capital and operation costs, financial mecha-nisms, estimated budget ▶ Skills required to run each system ▶ Environmental impact assessment	System scenarios are evaluated and optimised
	L Preliminary presentation of the results to the key stakeholders	Stakeholders are consulted and agreement is secured
	M Final selection of system options	
	N Workshop: Validation of chosen options by all the stakeholders	Proposals are validated by all stakeholders
	O Reassessment of key stakeholders according to the validated options	Influence and interest of stakeholders are reassessed according to the previous decisions

Detailed project development	**P** Detailed project development (Action Plan): ▶ Detailed design of the treatment plant ▶ Detailed definition of roles & responsibilities ▶ O&M management plan with clear allocation of costs, responsibilities and training needs ▶ Conventions between stakeholders, securing financial and institutional mechanisms ▶ Strategy for control and enforcement ▶ Definition of needs for capacity building and job creation ▶ Definition of contracts and bidding processes ▶ M&E strategy for the implementation phase ▶ Timeline for implementation with distinct phases and an itemised implementation budget	The Action Plan is validated by all stakeholders
	Q Reassessment of key stakeholders according to the Action Plan	Roles and responsibilities of stakeholders are redefined according to the Action Plan
▶ Detailed project document		
Implementation	**R** Recruitment of contractors for building and O&M	
	S Organisation of the sector, transfer of roles & responsibilities	FS management is transferred to the corresponding stakeholders
	T Capacity building / information campaigns	Awareness is raised among users; capacity is built where needed
	U Monitoring of construction	Building according to state-of-the-art is ensured
	V Reassessment of key stakeholders before inauguration of the FSTP	Capacity of stakeholders to deal with their new roles and responsibilities is assessed
	W Start-up of the system	The FSTP is brought to its state of equilibrium; stakeholders have acquired the necessary skills
	X Official inauguration ceremony	The FSTP is officially transferred to the city authorities / private entrepreneurs
M&E	**Z** Monitoring of the running system (technical stability, satisfaction of stakeholders, cost recovery)	The system is monitored to ensure its sustainability

Table 6 FSM planning framework (Strande et al. 2014)

Figure 19 Small-scale emptying and transportation service in partially accessible urban areas of Dar es Salaam

2. FSM APPROACHES

2.1 Roles and responsibilities

In Dar es Salaam various stakeholders have different responsibilities in ensuring adequate provision of sewage and sanitation services. The roles and responsibilities of Ministries, Regional Secretariat, LGAs, Water Supply and Sanitation Authorities (WSSAs), and community based organisations are clarified in the Water Supply and Sanitation Act, 2019. The implementation, management, operation and maintenance (O&M) of sanitation works are assigned to WSSAs. This includes centralised and decentralised structures for the emptying, transportation, treatment and safe disposal of sewage from communities (on-site sewage services) and sewerage network schemes (off-site sewage services).

In addition, community based organisations, NGOs and the private sector can own and manage decentralised water supply and sanitation schemes. The ultimate responsibility of providing sewage and sanitation systems falls under the Ministry of Water (MoW) and the President's Office – Regional Administration and Local Government (PO-RALG). The MoW shall be responsible for formulation of national policy and strategy, and for ensuring its execution. The Minister responsible for local government shall create a conducive environment for community and private sector participation and for water authorities and community organisations in the execution of their functions.

The provision of services by the WSSAs and the setting of tariffs are regulated and monitored by the Energy and Water Utilities Regulatory Authority (EWURA) (EWURA Act, 2001). Environmental aspects of wastewater treatment, stipulated in the National Environmental Policy (1997) and the Environmental Act (2004), are enforced by the National Environment Management Council (NEMC). At the national level, the National Sanitation Campaign establishes institutional links between the MoW, Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC), Ministry of Education, Science and Technology (MoEST) and the President's Office – Local Government Authority (PO-RALG) for coordinating the implementation of water, sanitation and hygiene promotion at the household level, public places and schools. Figure 21 presents the institutional arrangements for sanitation services.

Water Supply and Sanitation Act, 2019:

8. (2) The local government authorities may make bylaws in relation to water supply and sanitation to give effect to the efficient and sustainable provision of these services in their areas of jurisdiction [...]

13. (1) [...] a water authority shall do all things necessary to provide water supply and sanitation services to the area falling under its jurisdiction, [...]

16. (1)The ownership of waterworks, plant, equipment and other assets used by the Government, local government authorities or community organisations in connection with water and sanitation services together with any associated liabilities shall, without any compensation of the costs incurred, be transferred to the water authority upon its establishment.

19. (1) A water authority may, [...], arrange for the exercise and performance of all or any of its powers and functions under the licence by one or more agents, to be known as service providers.

23. (1) In the exercise of powers and the discharge of duties under section 21, a water authority shall take into account the existence and needs of the economically disadvantaged persons when [...]

Whereby: "sanitation" means the provision of appropriate facilities and services for the collection and disposal of human excreta and wastewaters; "sanitation works" means sewers, drains, pipes, ducts or channels, whether open or closed, used for the drainage of human excreta or wastewaters from buildings or land, and on-site systems for the reception of human excreta and waste.

Figure 20 <Sludge drying beds at Mlalakuwa-Kinondoni FSTP, Dar es Salaam

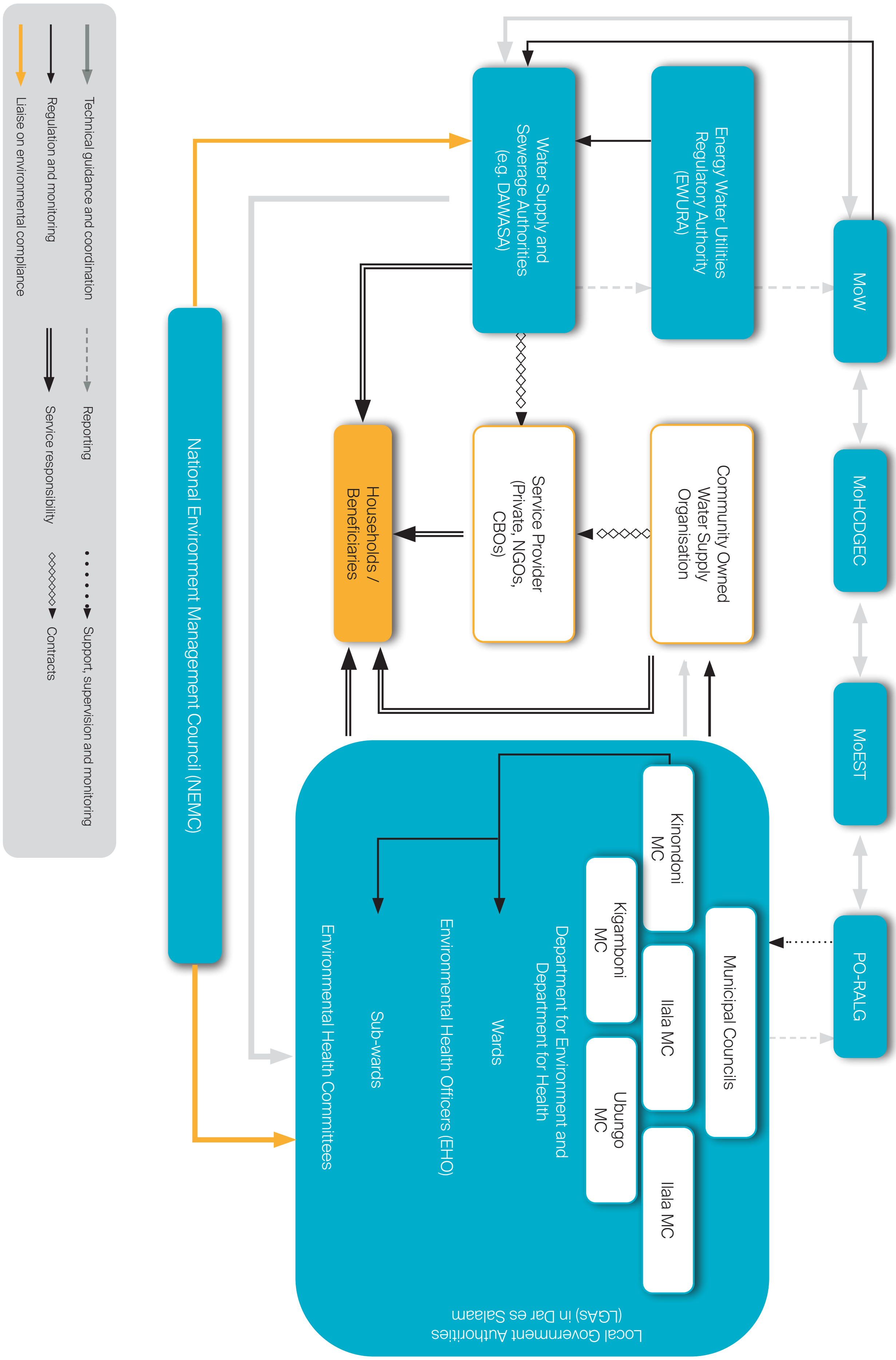
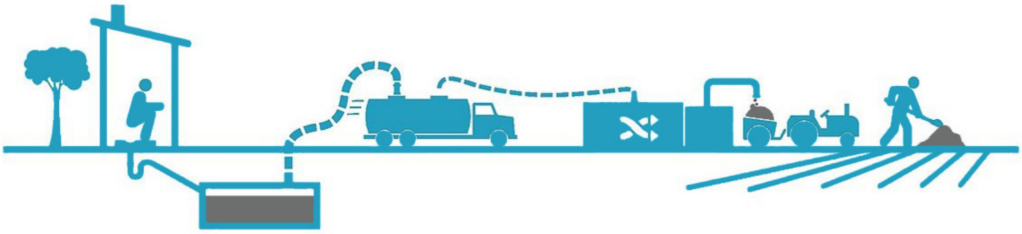


Figure 21 Overview of institutional structures that oversee the regulation of the sanitation sector in Dar es Salaam (modified from Brandes et al., 2015; MoW, 2008)

Effective planning, implementation and O&M of FSM requires appropriate institutional arrangements and legal frameworks along the entire FSM value chain. Sanitation is multi-sectoral and responsibilities are cross-cutting. Table 7 below highlights roles and responsibilities of different stakeholders, as well as challenges observed at different stages along the FSM value chain.



Stakeholders engaged					
	User Interface & Containment	**Emptying**	**Transport**	**Treatment**	**Reuse/Disposal**
Households, owners, users and artisans of toilets	—				
PO-RALG, LGAs	—	—	—	—	—
E&T service providers	—	—	—	—	
FSTP Operator		—	—	—	—
DAWASA and EWURA		—	—	—	—
Users of by-products and communities in the location of discharge					—
Communities at FSTP			—	—	—
Water Basin Authority-Ruvu					—
MoW, Wami Ruvu Basin Authority, MoEST, TBS, NEMC, NGOs, CBOs, DPs, financial Institutions, technical service providers	—	—	—	—	—

Current challenges related to roles and responsibilities	
Stage	**Challenge**
Overall system	▶ Insufficient awareness of the regulations and by-laws on sanitation ▶ Weak law enforcement
Containment	▶ Little improvement and upgrading of latrines ▶ Low annual budget for sanitation
Emptying and Transport	▶ Unhygienic practices, especially among informal emptiers ▶ Insufficient E&T equipment available to cover the demand
Treatment	▶ FSTPs owned by WSSAs do not meet the national effluent quality standards ▶ All centralised WSPs in Dar es Salaam are overloaded and not adequately maintained
Reuse/Disposal	▶ Legislation, institutional frameworks and community acceptance hinder the reuse of by-products (effluent, biogas and stabilised sludge)

Table 7 Observed challenges along the FSM value chain

Supporting literature

- Guidelines on OSS and FSM, by EWURA
- Public-Private Partnership Operational Guidelines for the Water Supply And Sanitation Sector, by EWURA
- The National Water Policy, by the MoW

2.2 Financial arrangements in FSM

▶ For every dollar invested in improved sanitation the global economic return is US$5.5
▶ For every dollar invested in water supply the global economic return is US$2.0
(UNESCO, 2019)

The general consensus is that investments in sanitation generate a benefit on the macro scale, as they prevent health and environmental problems. The costs for treating the effects of these problems in combination with the losses they cause are much higher than the costs for treating their causes (unsafe sanitation). In recognition of this, the Ngor Declaration (2015) states the commitment of African leaders to allocate 0.5% of GDP for effective sanitation service delivery by 2020.

Costs for FSM include capital expenditures (one-time investment (CAPEX)) and operational expenditures (continuous costs required to provide the regular services (OPEX)). Before implementing any FSM system, a clear strategy must be developed for how to cover these expenditures. When comparing FSM solutions, it is good to consider the costs over a reasonable time period (e.g. 10 years). Examples of these costs are listed in Table 8.

CAPEX	OPEX
Planning and design	Labour for O&M
Awareness creation during implementation	Awareness creation and marketing during O&M
Trainings for key stakeholders (e.g. operators)	Consumables for FS emptying, transportation and treatment equipment (fuel, lubricants, detergents, etc.)
Procurement of licences/permits	Cost of funding (interest)
Land acquisition	Office costs (rent & utilities, stationery, phone bills, etc.)
Labour for implementation	Personal protective equipment (PPE)
Procurement of material and equipment for construction (for entire value chain)	Regular maintenance of equipment and infrastructure
Procurement of E&T equipment	Licences for E&T service provision (annual registration licence from DAWASA)
Procurement of O&M equipment (for FSTPs)	Insurance for workers and equipment
Replacement of equipment	Taxes
Adaptation of the system	Discharge fee (if applicable)

Table 8 FSM CAPEX and OPEX

Supporting literature on financial arrangements in FSM

- Assad et al. (2018). Performance Audit Report on Provision of Sewage Services in Urban Areas.
- Mehta et al. (2019). Citywide inclusive sanitation through scheduled de-sludging services: emerging experience from India.
- Rao et al. (2020). Business models for fecal sludge management in India.
- Rao et al. (2016). Business models for fecal sludge management.
- Strande et al. (2014). Faecal Sludge Management: Systems Approach for Implementation and Operation

2.2.1 Costs of FSM

In an extensive study carried out in India, costs (CAPEX and OPEX) for FSM were evaluated (see Table 9). According to Rao et al. (2020) FSM requires much less financial capacity than networked sanitation (wastewater) systems. In the Indian context FSM was observed to be 46 times (CAPEX) and 12 times (OPEX) cheaper. This is logical when considering the reduced volumes produced, conveyed and treated in FSM systems compared to wastewater systems.

Representative data for FSM costs in Tanzania is still limited as only a few systems have been implemented. As can be observed in Table 9, CAPEX and OPEX for wastewater systems and FSM are highly variable and depend on various factors. Thus, costs for any system have to be determined for the specific context. For more details on costs for FSM, and willingness and ability to pay in the Dar es Salaam context, please see chapter 3 - FSM CASE STUDIES.

Options	CAPEX [USD per capita]	OPEX [USD per capita and year]
FSTP (100,000 PE)	2.10 - 2.60	0.20 - 0.40
FSTP and E&T	2.60 - 3.20	0.50 - 0.60

Table 9 Costs of FSM in the Indian context (Rao et al. 2020)

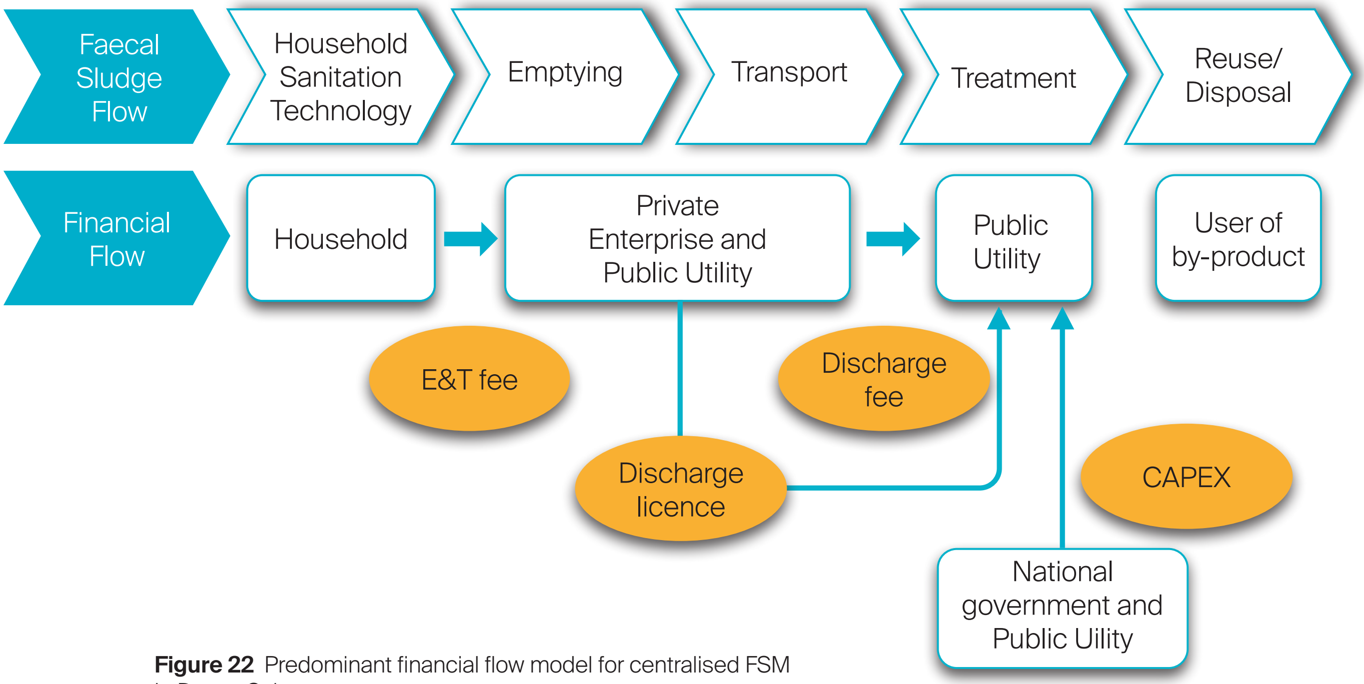


Figure 22 Predominant financial flow model for centralised FSM in Dar es Salaam

2.2.2 Current financial flow model for Dar es Salaam

In Dar es Salaam, FS E&T service is generally provided by private vacuum tank operators. These private businesses obtain income (E&T fees) from clients (e.g. households) with which they cover their CAPEX and OPEX. There is currently no regulation of fees. The private operators discharge at treatment plants operated by DAWASA for which they need to pay a discharging fee. Treatment infrastructure (CAPEX) is financed by the national government and DAWASA.

DAWASA is also starting to operate vacuum trucks, and will provide service for fixed tarifs in set zones. To date this public support is not sufficient to cover the demand for E&T and treatment services.

OPEX for treatment is covered by discharging fees and co-financed through the water bills that cover the costs of wastewater (from sewer networks) which is treated in the same treatment plants. The current financial flow model does not provide sufficient funds for adequate O&M of the treatment sites. In addition, the E&T system is not available for the entire population of Dar es Salaam, as the private service providers avoid low-income areas with limited access, where the business does not provide much or any profit. The current E&T fees are in a range of 10,000TZS to 20,000TZS per m^3, depending on multiple factors such as the volume collected, the accessibility of the containment system, and the distance between the client and the FSTP. Currently E&T service providers need to pay a discharge fee of 5,000TZS (for less than $7m^3$) and 10,000TZS (for $7m^3$ – $20m^3$).

Reuse of the effluent of centralised FSTPs (WSPs) in Dar es Salaam is currently not intended. Thus there is no revenue from the sale of by-products. Nevertheless, informal and indirect reuse of the effluent is present, as small-scale farmers and gardeners use the water from drains and rivers which contain effluent from the WSPs.

2.2.3 Alternative financial flow models

Apart from the conventional financial flow model there are several other pilot systems and informal arrangements. CBOs and NGOs are testing models where the private sector, the CBO or the NGO provides E&T services as well as O&M of the FSTPs. The costs for the entire service provision are expected to be fully recovered by the E&T fees. Due to low E&T fees and relatively high costs for O&M, scaling up these cost recovery models seems challenging, but the sustainability of such projects is currently being tested. Other informal E&T services reduce costs through unsafe practices, including illegal dumping into the environment, which make them affordable. These service providers are able to generate profits, even when they depend solely on E&T fees.

The aim of FSM financial flow models shall be the provision of affordable E&T services and at the same time sufficient funds for safe and sustainable O&M along the entire FSM value chain. In doing so, illegal dumping shall be prevented at all stages of the value chain. Public-private partnerships (PPP) shall assist the government in extending service coverage using investment from the private sector. For PPPs to succeed, the government shall provide an enabling environment for private businesses, but at the same time regulate the businesses to ensure affordable and safe service provision to all. The government is also responsible for ensuring that the parts of the value chain which are not profitable for a private business get subsidised, or are provided directly by the government (e.g. through DAWASA).

In conventional FSM PPPs, the private sector provides E&T services. Nevertheless, there are also other successful models whereby the private sector takes over tasks including E&T and also treatment. In an optimal case the treatment by-products can generate additional income when they are sold to agricultural or industrial operations. In Tanzania the formal reuse of treatment by-products is hindered due to the absence of regulations and standards for by-products. Formalising safe reuse practices would open up the markets for treatment by-products.

An improved financial flow model for the Dar es Salaam context can include a financial flow from the generators of the FS to DAWASA (see Figure 20 and Table 10). This enables DAWASA to cover OPEX of the FSTPs and also to provide E&T services in challenging areas where private business is not feasible. The financial flow can be in the form of a sanitation levy which is included in water bills or added to property taxes. In addition, the national government of Tanzania needs to provide funds for CAPEX where the private sector cannot invest. With high certainty this is required for the implementation of FSTPs. To cover the demand, this financial support must be higher than in the past. More details on this model need to be clarified based on field data and evaluation of existing drivers and barriers (evidence-based decision making).

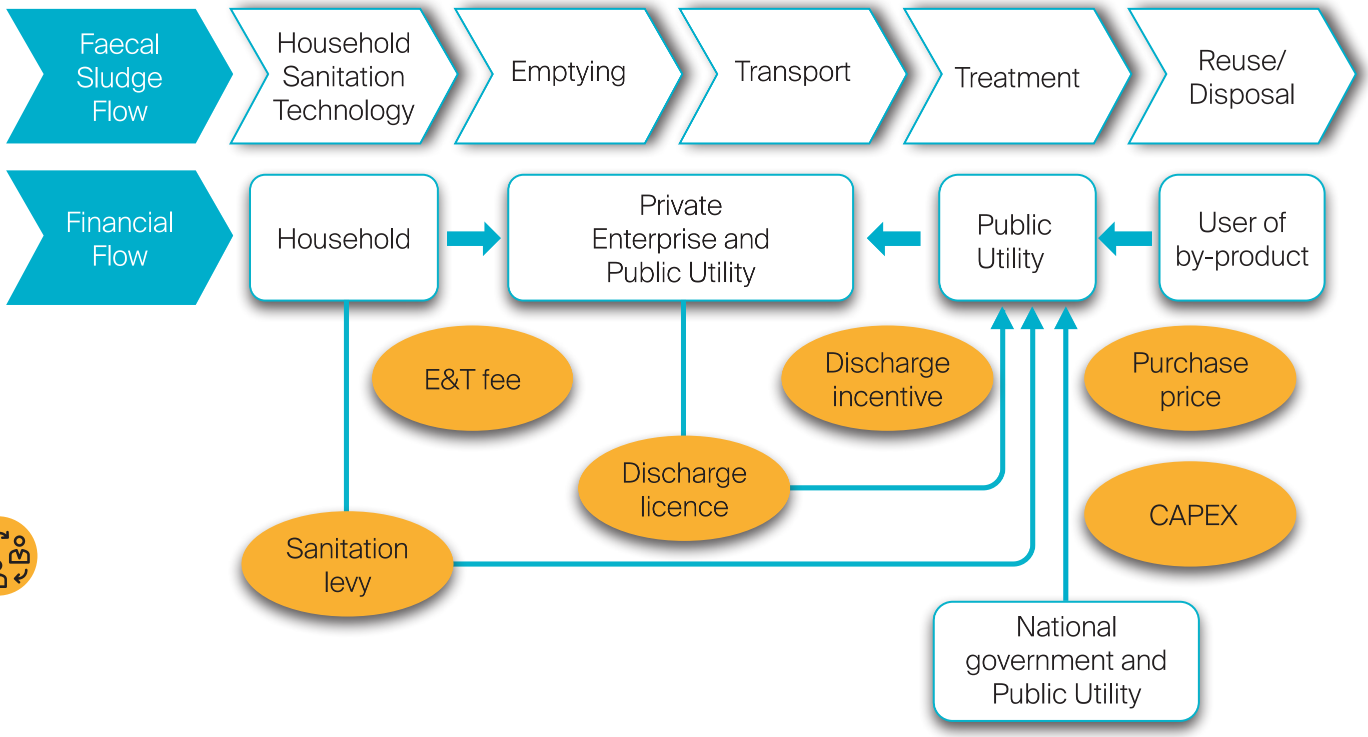


Figure 23 Optimised financial flow model for FSM in Dar es Salaam

Pros	Cons
E&T fees can be low and affordable for all households.	There is an additional financial burden on the household due to the presence of a sanitation levy, on top of an emptying fee.
Public utility will get budget support from households (sanitation levy); hence, it will be in a better position to operate and maintain the facilities.	E&T operators might not be able to purchase the discharge licence in the case of low demand for E&T services.
Discharge fee will be turned into discharge incentives; thus, private enterprise is motivated to discharge at the FSTP.	Households with sewer connections will be financially privileged in comparison to households with on-site sanitation systems, as the latter need to pay for E&T services in addition to the sanitation levy on water bills, and also need to pay for the implementation of on-site containment systems.
Budget support (CAPEX) from the national government will increase treatment capacity. As an additional benefit, the production of by-products will increase. Selling the by-products can lead to additional income for the public utility.	Households with no water connection will also not pay the sanitation levy, but might still request the subsidised E&T services. (This could also be a “pro”, assuming that households with no water connection are disadvantaged, and thus require subsidised E&T services.)

Table 10 Pros and cons of the suggested optimised financial flow model

2.2.4 Private sector investment in FSM

Enabling the private sector to invest in FSM is key to a sustainable cost recovery model. Currently in Dar es Salaam private FSM businesses are quite limited. Reasons for this are listed in Table 11 (barriers). Possible drivers which enable FSM businesses were identified within the working groups and are also listed in Table 11 below.

Barriers	Drivers
FSM business is new to the sector, thus little knowledge, experience and data is available	Development of business capacities (trainings) for FSM enterprises
FSM is perceived as a service, not a business, thus the willingness to pay is quite low	Development of financial products, with specified terms and conditions for FSM
Start-up equipment costs are too high for FSM service providers	Data collection and research are required
Financial institutions do not have experience in FSM, which makes it very difficult for small FSM businesses to receive loans	The government must support FSM businesses as they are also a public service (e.g. by supporting start-ups, or by declaring tax exemptions)
Small FSM entrepreneurs cannot provide the requested collateral	To generate income from FSM by-products, the market for by-products has to be developed
High uncertainties and lack of competition among financial institutions lead to high interest rates	Sanitation businesses are more successful when offering several services/products, e.g. E&T, toilet unblocking, sales of by-products, toilet and containment maintenance/upgrading
Lack of business knowledge (e.g. preparation of solid business plans) disqualifies many enterprises	LGAs must assist in creating awareness and demand, and also by enforcing laws
The willingness to enter the business is low as it is socially not highly regarded, thus obtaining committed workers is also challenging	E&T and discharge fees shall be regulated to enable good financial planning
Coordination among FSM stakeholders is very low	Awareness creation in communities to promote the advantages of safe sanitation
Low reliability on fixed tariffs, leading to insufficient legislative certainty for investment	Marketing of FSM services
	Involve political leaders in campaigns for promoting sanitation
	Enable and encourage crowd funding, where community members contribute to enable the start-up of a sanitation service in their community

Table 11 Barriers and drivers for the private sector to invest in FSM

2.2.5 Innovative approaches to FSM logistics for cost reduction

The utilisation of E&T equipment can be optimised by better connecting clients and service providers. This would reduce the waiting times for service; reduce the distance between customers, service providers and FSTPs; reduce the time spent per trip; and eventually reduce OPEX. This can be achieved with the help of a call centre which connects clients, service providers and decentralised FSTPs. The call centre can then connect free-floating E&T equipment with the nearest clients and FSTPs. The call centre can also allocate the correct E&T equipment to the client (mainly depending on volume of FS to be emptied and accessibility of the containment system). A call centre helps to enable an approach that combines decentralised treatment and centralised management (deCENT–FSM). Costs (CAPEX and OPEX) can be reduced and service coverage can be extended (also to conventionally inaccessible areas), by implementing and operating FSM at the optimal level of decentralisation with an optimal combination of small and large-scale services (see Figure 24 below).

Centralised management can enable the approach of scheduled emptying, which further increases the efficiency of the entire system, compared to the current on-demand service provision. A detailed analysis on scheduled emptying is provided by Mehta et. al (2019).

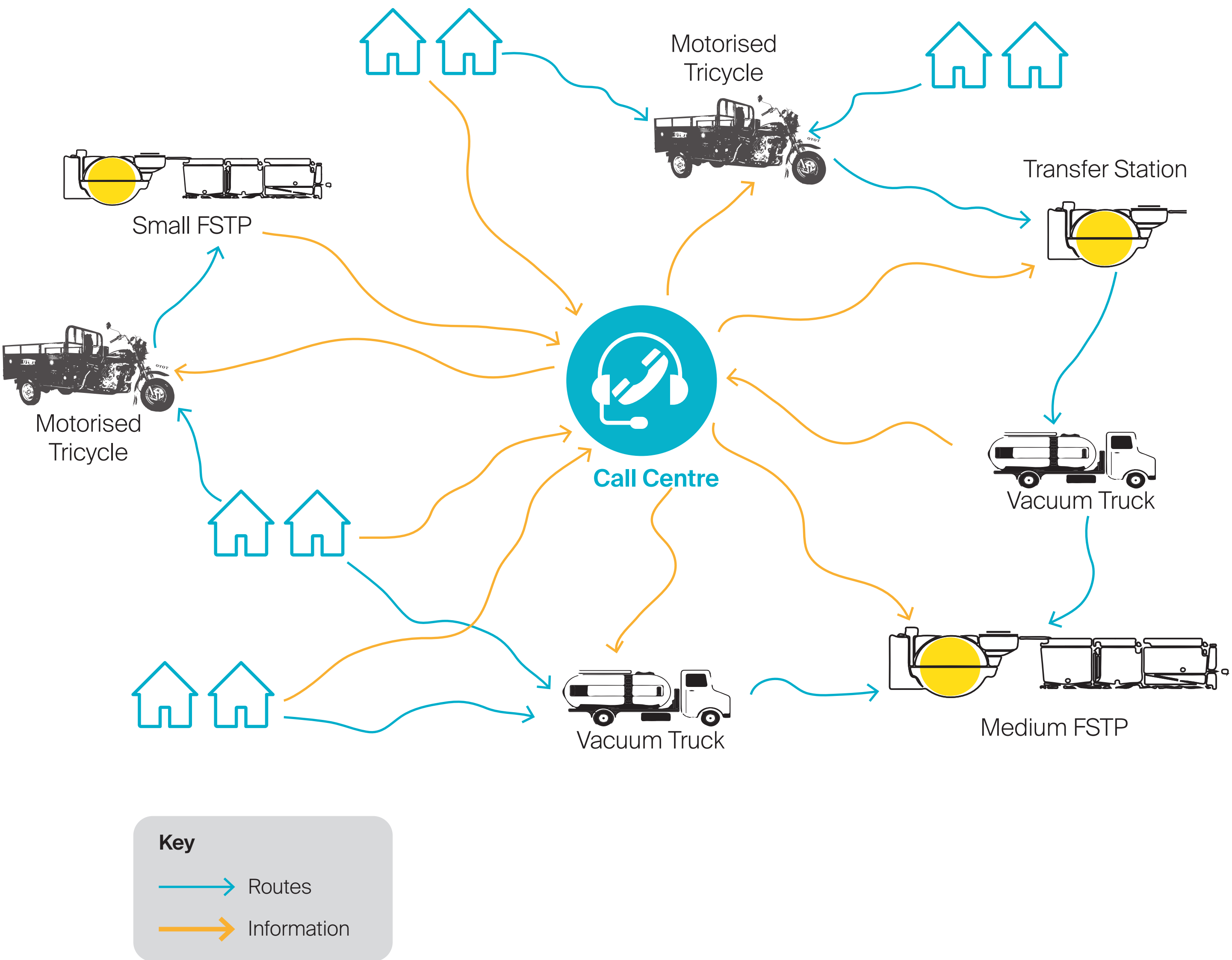


Figure 24 FSM operational model of decentralised treatment and centralised management, using a call centre for service coordination

A smartphone app for city-wide tracking and connecting of service providers can replace or assist the call centre (e.g. “UBER” for FSM, see Figure 25). In addition to the benefits listed above for the call centre, the app can collect data which helps service providers and public utilities to monitor, evaluate and optimise service provision. The app can also enable the controlling of service providers, e.g. to limit illegal dumping, overloading of FSTPs or over-pricing (E&T fees). Furthermore, the app can enable targeted subsidising of services (e.g. based on the area served). By directing service demands which are not accepted by private providers to the public utility, the app can help to enable the combination of private FSM services (in areas where business is feasible) and public services by the utility (in areas where cost recovery is challenging).

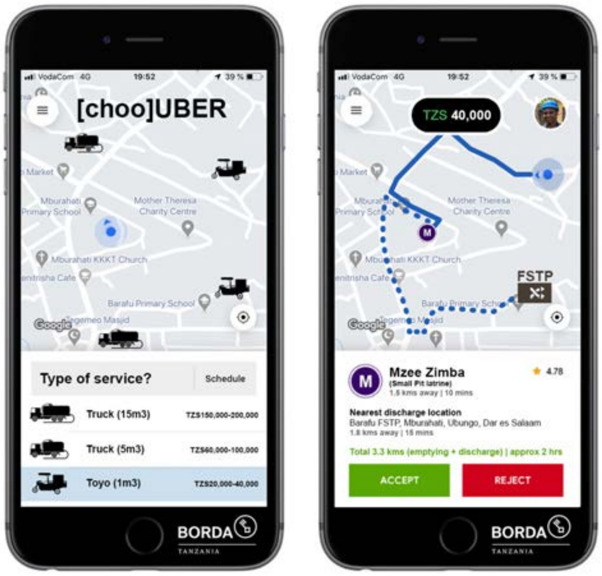


Figure 25 [choo]UBER - FSM app; for clients (left) and service providers (right)

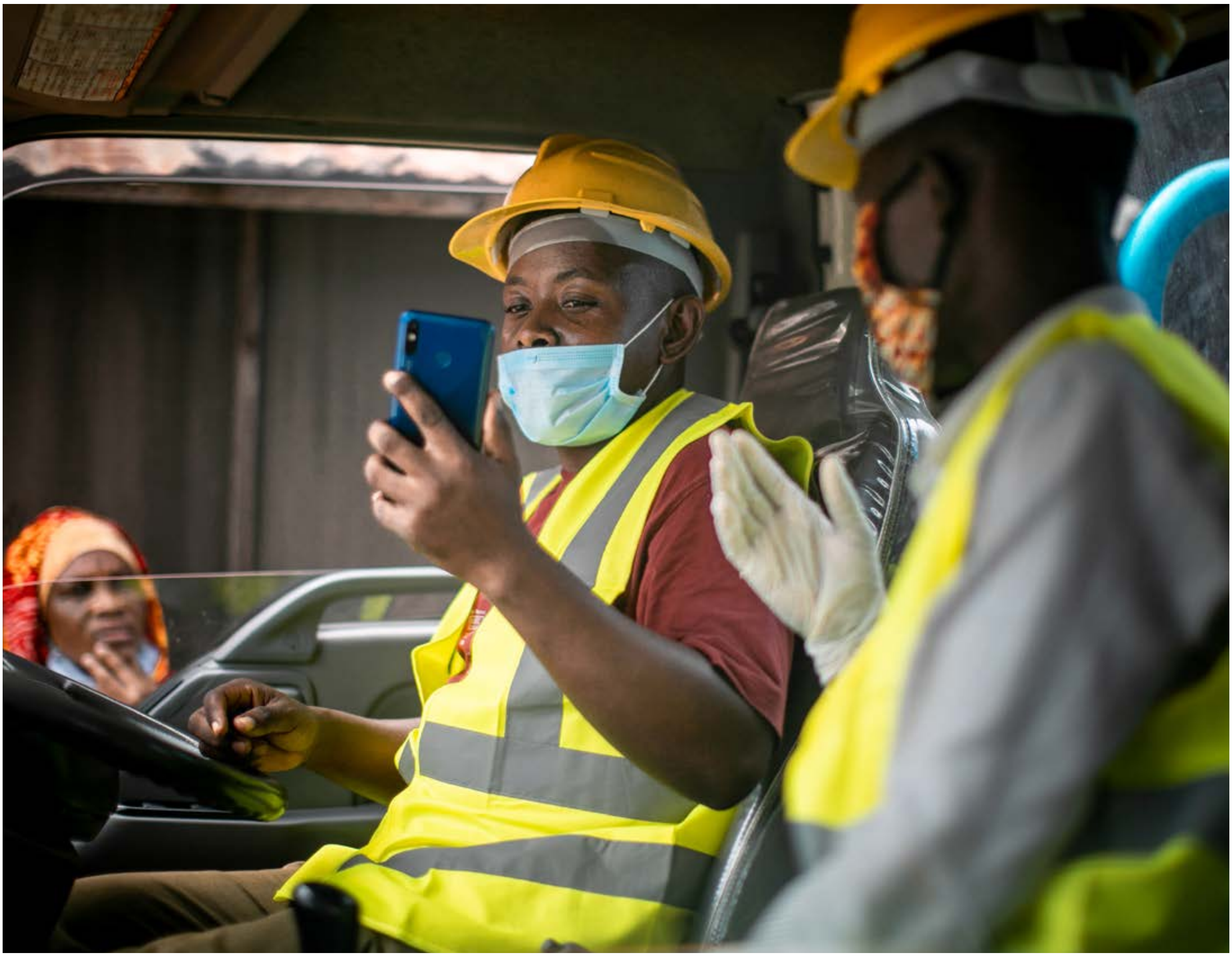


Figure 26 Service coordination: locating the customer while providing E&T service with a vacuum truck

2.3 Standards for FSM effluent and by-products

2.3.1 Current discharge standards in Tanzania

The Tanzania Bureau of Standards (TBS) is the statutory national standards body for Tanzania, which formulates, promulgates and implements national standards. The formulation of discharge standards follows a national standardised participatory process based on the "consensus principle" which makes use of technical committees. These committees are formed by several stakeholders, usually members of industries, government, ministries, research institutions, higher learning institutions, business organisations and final consumers.

Currently, wastewater discharged to water bodies need to comply with TZS 860:2005 "Tolerance Limits for Municipal and Industrial Wastewaters" (see Table 12 for details).

Currently (2021), TBS is developing new standards for "Faecal sludge management – permissible limits for use and disposal". These standards will recognise the difference between small-scale and large-scale FSTPs. The limits will be specific for cases of discharge to inland surface water and reuse for irrigation. The standards will also include limits for reuse or disposal of dried sludge.

Parameter	Limit
BOD5 at 20°C	30 mg/l
COD	60 mg/l
pH range	6.5-8.5
Total suspended solids (TSS)	100 mg/l
Nitrates (NO3-)	20 mg/l
Phosphorus total (as P)	6 mg/l
Total coliform organisms	10,000counts/100mL

Table 12 Tolerance limits for municipal and industrial wastewaters discharge (TZS 860:2005)

More information on guidelines and standards for wastewater

▶ Assad et. al (2018). Performance Audit Report on Provision of Sewage Services in Urban Areas.

▶ FAO (1992). Wastewater treatment and use in agriculture - FAO irrigation and drainage paper 47.

▶ Kihila et al. (2015). A review of the challenges and opportunities for water reuse in irrigation with a focus on its prospects in Tanzania.

▶ Kramer et al. (2003). Guidelines and Standards for Wastewater Reuse. In Technical University Hamburg-Harburg (Ed.)

▶ McConville et al. (2020). Guide to Sanitation Resource Recovery Products & Technologies - A supplement to the Compendium of Sanitation Systems and Technologies.

▶ UN-Water (2017). Wastewater: The untapped resource.

▶ VPO (2013). Guidelines on management of liquid waste. Dar es Salaam: Vice-President's Office (VPO), The United Republic of Tanzania.

▶ WHO (2001). Water Quality: Guidelines, Standards and Health: Assessment of risk and risk management for water-related infectious disease. IWA.

▶ WHO (2006). Guidelines for the safe use of wastewater, excreta and greywater. Volume 2: Wastewater use in agriculture.

▶ WHO (2018). Guidelines on sanitation and health. Free PDF available at: www.who.int/water_sanitation_health/publications/guidelines-on-sanitation-and-health/en/

2.3.2 Existing gap between effluent standards and current practice

The existence of effluent standards, sewer networks and treatment plants will not lead to adequate FSM, if there is no clear and consistent monitoring and law enforcement. The EWURA Regional Water Annual Performance Reports (2018) revealed that many of the wastewater treatment plants owned by WSSAs do not meet the national effluent standards (Figure 27). Some of the reasons for failure to meet the national discharge standards include a dilapidated and overloaded infrastructure and irregular maintenance of treatment facilities (e.g. pending desludging of ponds). This is due in part to insufficient funds for adequate wastewater and FS management.

Some untreated wastewater is formally discharged to the ocean without meeting the discharge standards (wastewater outlet to the ocean). In addition, the illegal discharge of FS and wastewater to surface water bodies or infiltration into the soil is still a common practice in Dar es Salaam.

Informal reuse of treated and untreated wastewater and FS is a common practice in (peri-)urban areas (e.g. Msimbazi or Mlalakuwa, where the effluent of WSPs or surface water with high concentrations of human excreta is reused for irrigation or car washing). Also, the reuse of water from drenches, which mainly consists of greywater and the effluent from pit latrines and septic tanks, is popular in Dar es Salaam (as seen in Figure 32). As the informal reuse of untreated or only partially treated wastewater is currently common practice, new standards for irrigation shall be set to achievable and enforceable levels in the short term. In the long term, if the technology and financial resources allow the implementation of complex systems with higher treatment performance, stricter standards could be set for reuse types with high risk of infection (see chapter 1.2.7 - Stepwise implementation).

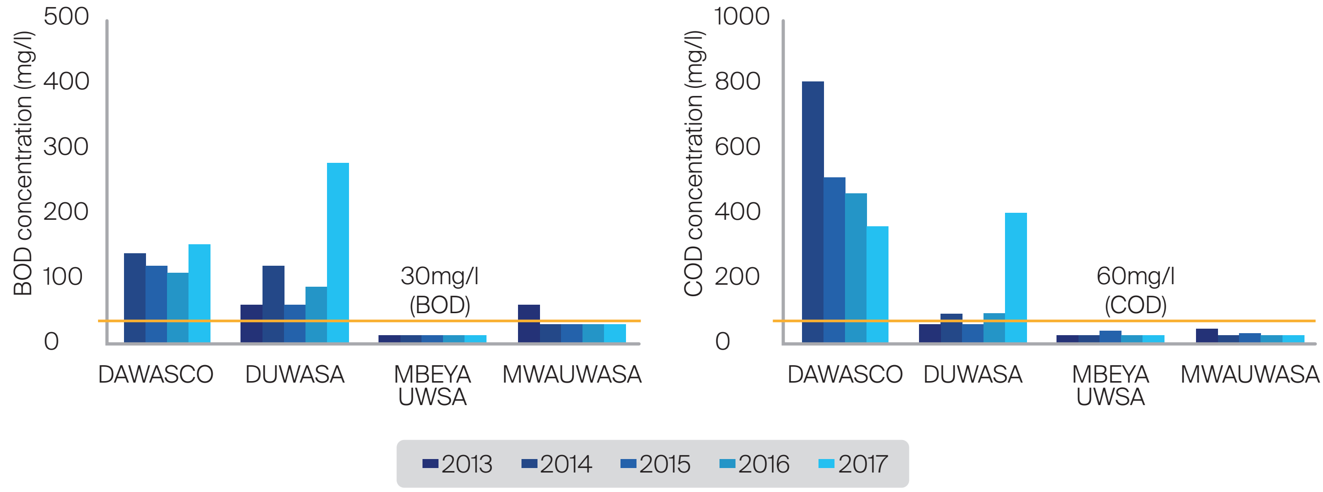


Figure 27 BOD and COD levels in the effluents of waste stabilisation ponds from different UWSSAs from 2013–2017 (adapted from Assad et al. 2018)

2.3.3 Way forward on standards

In the working group meetings that provided input for this guide, it was agreed that in the short term the sanitation sector needs to focus on developing the following standards:

- Standards for small-scale treatment plants
- Standards for reuse, focusing on landscape irrigation (standards for other types of irrigation shall follow)
- Standards for different receiving water bodies (e.g. rivers and lakes, ocean and infiltration)

According to the WHO (2001), the development of water quality standards shall consider the following aspects:

- The implementation of national effluent standards must be closely linked to the adoption of adequate technologies for the treatment of wastewater (and FS).
- Control agencies and financial institutes should license and fund control measures (e.g. wastewater treatment plants) which allow for stepwise improvement of water quality.
- Standards should reflect water quality criteria and objectives, based on the intended water uses.
- Control technologies should be within the countries' financial conditions. The use of appropriate technology should be always pursued.
- Monitoring requirements and frequency of sampling should be defined, in order to allow proper statistical interpretation of results. The cost implications for monitoring need to be taken into account in the overall regulatory framework.
- It should be clear how to interpret the monitoring results and the related compliance with the standards (e.g. mean values, maximum values, absolute values, percentiles or other criteria).
- The efficient implementation of standards requires an adequate infrastructure and institutional capacity to license, guide and control polluting activities and enforce standards.

The effect of discharging liquid waste to different types of waterbodies and the resulting requirements for treatment are well stipulated in the "Disposal of Treated Liquid Waste into the Environment" chapter of the Tanzanian "Guidelines on Management of Liquid Waste" (2013). Currently, to comply with Tanzanian discharge standards, it is necessary to increase the number of treatment modules which leads to increased CAPEX and OPEX. In 2018 the Ministry of Water presented an analysis of decentralised wastewater treatment solutions (DEWATS) which included the module combination required to fulfil with the Tanzanian discharge standards (see Table 13). For more details on the treatment efficiency of FSTPs in the Dar es Salaam context, please see chapter 3 - FSM CASE STUDIES, Table 27 - Treatment performance of FSTPs in Ubungo, Temeke and Kinondoni.

Outlet	Biogas settler and ABR	Biogas settler, ABR, AF and PGF	Septic tank, ABR, AF, vertical sand filter, UV
TSS (mg/l)	250	30	25
COD (mg/l)	350	100	60
PO4-P (mg/l)	15	10	6
NH4-N (mg/l)	87	70	10
Faecal coliforms (CFU/100ml)	10^7	10^5	103

Increasing costs

Table 13 DEWATS module combination for wastewater treatment and their outlet parameters (MoW, 2018)

Achieving high discharge standards may be unaffordable, and also not highly important when treating and discharging only small volumes. A receiving water body has the capacity to bear a specific amount of pollutant without any severe impact on the ecosystem or on public health. The relevant factor to be controlled is the loading of pollutant that is discharged to a receiving water body (see Equation 1 below).

Equation 1
Loading [mass] = Concentration [mass/volume] x Volume [volume]

Taking Equation 1 into account creates the consensus that small-scale treatment plants, in comparison to large-scale treatment plants, do not need to achieve the same level of pollutant concentrations in their effluent as long as they discharge over a number of receiving water bodies. Thus, the effluent concentration shall be in relation to the volume of the discharged water (per time) and the capacity of the receiving water body to naturally degrade the pollutants. The higher concentration in the receiving water body caused by the discharge of a higher volume of water with constant concentration is visualised in Table 14.

Large-scale treatment plant		Small-scale treatment plant	
Volume of effluent and concentration of pollutant discharged to the receiving water body			
● ● ● ●		●	
Receiving water body, before and after receiving effluent			
Before	After ● ● ● ●	Before	After ●

Table 14 Effect of discharging different volumes with constant concentrations

Figure 28 Inauguration ceremony for Mburahati-Ubungo FSTP

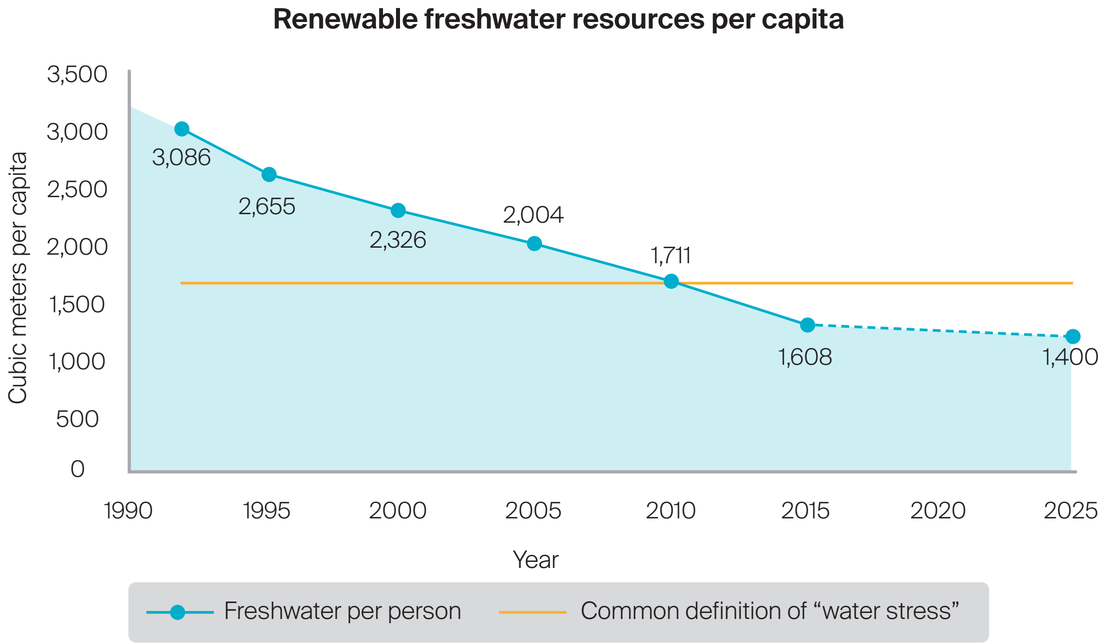


Figure 29 Renewable freshwater resources per capita in Tanzania (World Bank Open Data)

Wastewater is a resource; therefore its reuse should be reinforced through the development of standards. Tanzania is a water-stressed country (see Figure 29). As the total renewable water resources are limited and the population is rapidly growing, the available water per capita is continuously decreasing. Reusing water reduces per capita demand and thus enables sufficient water supply even with an increasing population.

Standards for landscape irrigation are a priority, as there is comparably low risk associated with this type of reuse. This practice also has high potential to be scaled up in the urban context of Dar es Salaam. When implementing FSTPs, it is often challenging to identify an adequate option for reusing or discharging the effluent. Landscaping is one reuse type which is feasible in most areas of Dar es Salaam. In addition, this has the advantage of increasing the community acceptance of an FSTP, as it brings the benefits of nature to the communities.

For all irrigation reuse practices, health risks have to be minimised. The standards which shall control these risks must mainly consider the types of risks listed in Table 15. However, the feasibility of complying with the standards is of high importance.

Type of Risk		Examples
Biological	Bacteria[1] Helminths[1] Protozoans[1] Virus[1] Schistosoma[2]	E. coli, Vibrio cholerae, Salmonella spp., Shigella spp. Ascaris, Ancylostoma, Tenia spp. Intestinal Giardia, Cryptospridium, Entamoeba spp. Hepatitis A and E, Adenovirus, Rotavirus, Norovirus Blood-flukes
Chemical	Heavy metals[2] Hydrocarbons[2] Pesticides[1]	Arsenic, Cadmium, Mercury Dioxins, Furans, PCBs Aldrin, DDT

[1]Contact and/or consumption; [2]Consumption

Table 15 Biological and chemical risks associated with the use of raw wastewater in agriculture (WHO, 2006)

2.4 Optimised technical solutions for FSM in Dar es Salaam

There is a large variety of technologies for FSM. There are different technical solutions for each stage of the FSM value chain. Each technology has attributes that suit specific circumstances. Some major attributes that need to be considered during technology selection are listed in Table 16 below. These key attributes are briefly described for all preselected technologies presented in the fact sheets in chapter 2.5.2 Emptying and Transportation Technologies and in chapter 2.5.3 Treatment Technologies. For specific experience on technologies for FSM in the Dar es Salaam context, please see chapter 3 - FSM CASE STUDIES.

Key attributes that need to be considered during technology selection
▶ OPEX
The higher the OPEX, the higher the risks of system failure due to inadequate O&M.
▶ CAPEX
The higher the CAPEX, the higher the risks of system failure due to inadequate O&M.
▶ Level of mechanisation
The higher the level of mechanisation, the lower the space requirements and the higher the treatment performance; but the higher the level of mechanisation, the higher the O&M costs, the higher the required skills and capacities, and the lower the availability of spare parts.
▶ Energy consumption
The higher the dependence on energy, the higher the operational costs and the higher the risk of system failure due to power cuts.
▶ Requirement of skilled labour for implementation, operation and maintenance
The higher the requirement for skilled labour, the higher the challenge of obtaining adequate services and thus the higher the dependence on foreign service providers.
▶ Requirement of spare parts
The more complex the procurement of spare parts, the higher the risk of system failure due to temporary unavailability of parts.
▶ Space requirements
The higher the space requirements for an FSTP, the more challenging the identification of a site for treatment.
▶ Treatment efficiency
The higher the efficiency of a system, the higher its complexity.

Table 16 Key aspects to consider during technology selection

Detailed guidance on the implementation of FSM systems and the design of FSTPs

▶ Gensch et al. (2014). Compendium of Sanitation Technologies in Emergencies.
▶ McConville et al. (2020). Guide to Sanitation Resource Recovery Products & Technologies - A supplement to the Compendium of Sanitation Systems and Technologies
▶ MoW (2018). Guidelines for the Application of Small-Scale, Decentralised Wastewater Treatment Systems.
▶ MoW (2020). Design, Construction Supervision, Operation and Maintenance (DCOM) Manual for Water Supply and Sanitation Projects, 4th Edition.
▶ Strande et al. (2014) Faecal Sludge Management: Systems Approach for Implementation and Operation
▶ Tayler (2018). Faecal Sludge and Septage Treatment.
▶ Tilley et al. (2014). Compendium of Sanitation Systems and Technologies.

The selection of a technology is based on the objectives of the FSM system, the specific needs and the local constraints. The aim of planners and designers shall be to select an optimised, robust combination of technologies along the entire FSM value chain. During a feasibility study, the preselected technologies need to be evaluated within the local context. Key aspects to consider are listed in Table 17 below.

Key aspects of technology selection that need to be considered during the feasibility study
▶ Availability of funds for implementation
▶ Availability of funds for O&M
▶ FS characteristics (quality and quantity)
▶ Availability of skilled labour for implementation, operation and maintenance
▶ Availability of land for the construction of an FSTP
▶ Options for reuse and/or disposal of by-products
▶ Availability of spare parts for the selected technologies
▶ Soil characteristics (for construction and reuse/disposal (e.g. infiltration)
▶ Groundwater characteristics
▶ Risks of pollution (e.g. nearby wells or surface water bodies)
▶ Accessibility of treatment site, and distance between the FSTP and the clients (households)
▶ Local climate and natural hazards (e.g. flooding)
▶ Risks of nuisance (e.g. smell, noise or insects)
▶ Social and cultural acceptance of the technologies
▶ Availability of water and electricity
▶ Availability of professional services (e.g. for maintenance or sampling (laboratories))
▶ Availability of consumables (e.g. chemicals, detergents or lubrications)
▶ Local legislation, institutional arrangements and government support

Table 17 Key aspects to consider during the feasibility study

User-friendly and safe FSM systems

The user-friendliness of an FSM system, and the health and safety of its operators, shall always be the highest priorities. It is essential to make O&M tasks as convenient and safe as possible. These aspects need to be considered in the early stages of system design and technology selection. National occupational safety and health (OSHA) standards must be complied with. The first and best method of risk mitigation is limiting exposure to hazards. This is done by providing Personal Protective Equipment (PPE) for sanitation workers (as demonstrated in Figure 27) and trainings on proper application of standard operating procedures (SOPs), tools and equipment.

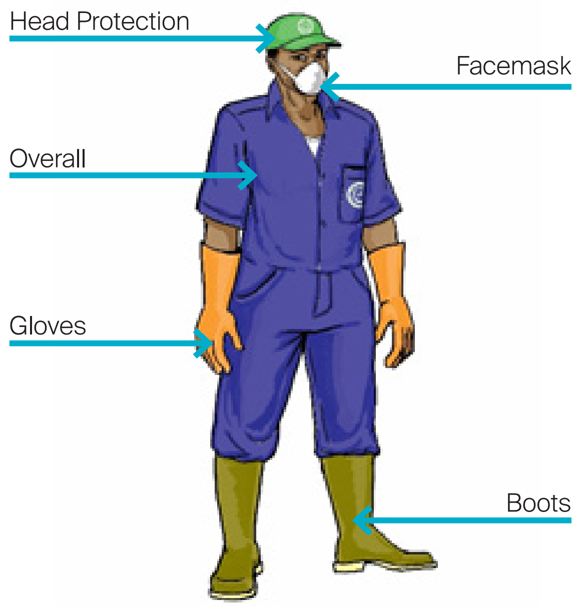


Figure 30 Basic PPE for sanitation workers

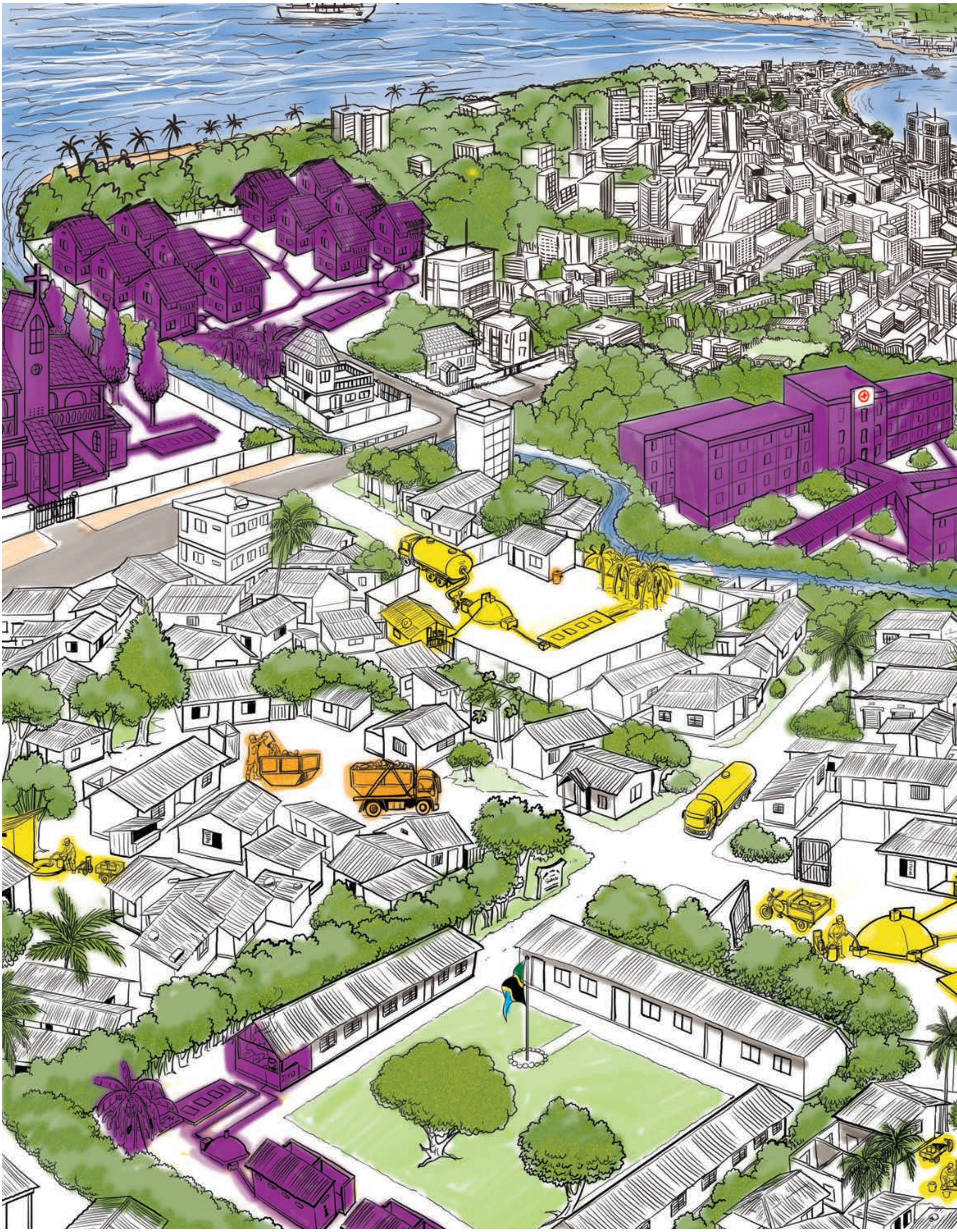


Figure 31 Decentralised sanitation solutions (wastewater (purple), faecal sludge (yellow) and solid waste (orange)) demonstrated for contexts in Dar es Salaam

2.4.1 User interface and containment technologies

User interface and containment technologies will not be presented in detail in this guide, as they are well described in other sources. For further guidance we recommend referring to the sources provided in the box below. Within this guide we would only like to point out the importance of these segments of the FSM value chain, as they are at the beginning of the chain and thus influence all following modules.

Correct practices at the user interface (e.g. solid waste management and control of what enters the containment system), as well as improved construction of containment systems (mainly focusing on emptyability and water tightness) are key to a well-functioning FSM value chain.

Detailed guidance on the implementation and operation of toilets (user interface and containment)

- MoHCDGEC (2014). Mwongozo wa ujenzi wa vyoo bora na usafi wa mazingira
- People's Development Forum (PDF) et al. (2013). Bidhaa za usafi wa mazingira kwa bei nafuu: CHOO BORA na MAZINGIRA SAFI. Wlaya ya Chamwino.
- Tilley et al. (2014). Compendium of Sanitation Systems and Technologies.
- WEDC (2004). Catalogue of Low-cost Toilet Options: for Dar es Salaam.

Figure 32 Informal reuse of grey- and blackwater for the cultivation of sugarcane in Dar es Salaam

2.4.2 Emptying and transportation technologies

The major aspects to be considered during the selection of E&T technologies are (1) the accessibility of containment systems, (2) the FS characteristics, (3) the volume of FS to be emptied and transported, (4) the distance between containment system and FSTP, (5) availability of skilled labour for O&M, and (6) the available funds to cover CAPEX and OPEX of the E&T equipment. In the following fact sheets, technologies are presented which have been preselected for the Dar es Salaam context.

Gulper	
Purpose	Emptying of FS containment systems
CAPEX	LOW
OPEX	LOW
Strengths	▶ Can be used in inaccessible areas ▶ Can be manufactured locally
Weaknesses	▶ Emptying is rather slow and requires physical work ▶ Workers are exposed to health risks ▶ Challenging in the presence of solid waste ▶ Can only empty the upper 0.8m of a containment; is only applicable for thin but not very wet FS.
Remarks	The gulper is only appropriate in very inaccessible areas, and when other technologies are not feasible (e.g. due to limited funds or unreliable electricity). It is appropriate for replacing pure manual emptying. As it is labour intensive, it creates jobs. It can pump up to 3l/stroke.

eVac	
Purpose	Emptying of FS containment systems
CAPEX	HIGH
OPEX	LOW
Strengths	▶ Can be used in inaccessible areas ▶ High suction power
Weaknesses	▶ Requires electricity, although a new pilot is available with a petrol engine (eVac Mk 5) ▶ Carrying the extracted FS to the transport is tough physical work
Remarks	It is not yet manufactured in Tanzania, but local manufacturers estimate its production to be feasible. *An eVac Mark 4 is currently being tested in Dar es Salaam by BORDA. This model has an expected working vacuum pressure of 0.6 to 0.7 bar. A 1.5kW/ 240V electrical engine powers the vacuum pump. For the FS characteristics typical in Dar es Salaam this is sufficient to pump FS at a rate of 2-5l/s.*

Flexcrevator/ excluder	
Purpose	Emptying of FS containment
CAPEX	HIGH
OPEX	LOW
Strengths	▶ Can be used in inaccessible areas ▶ Can be used for pits containing solid waste ▶ Can be combined with a vacuum truck
Weaknesses	▶ Very high CAPEX ▶ Includes many parts to be transported and cleaned
Remarks	Still in pilot phase and difficult to obtain. Could be a solution for pits with much solid waste, but only if produced in larger numbers to reduce the CAPEX.

Trash pump	
Purpose	Emptying of FS containment
CAPEX	MEDIUM
OPEX	MEDIUM
Strengths	▶ Uses petrol and thus is independent from electricity supply ▶ Can suck and push the liquid ▶ Is mobile and can access all areas
Weaknesses	▶ Is limited to a particle size of app. 15mm ▶ Is relatively heavy (app. 65kg)
Remarks	This is a good alternative for FS that is free of solid waste.

SludgeGo (vacuum system)	
Purpose	E&T of FS
CAPEX	HIGH
OPEX	MEDIUM
Strengths	▶ Can access many areas ▶ Is easy to operate (little manual work)
Weaknesses	▶ Can transport only small volumes (800l) ▶ Cannot access all areas
Remarks	Is still in the pilot stage, and thus costs for manufacturing are high; nevertheless, it was and can be manufactured in Tanzania.

Motorised tricycle	
Purpose	Transportation of FS
CAPEX	LOW
OPEX	LOW
Strengths	▶ Locally available ▶ Can reach even less-accessible areas
Weaknesses	▶ Low carriage capacity ▶ During rainy season access to clients can be challenging ▶ Cannot access all areas
Remarks	The carrying capacity can vary between 700 – 1500kg, depending on the model. A motorised tricycle always needs to be combined with an appropriate pit emptying tool.

Vacuum truck	
Purpose	E&T of FS
CAPEX	MEDIUM
OPEX	MEDIUM
Strengths	▶ High carriage capacity ▶ Can do E&T ▶ Fast emptying possible ▶ Easy to operate
Weaknesses	▶ Import can be challenging ▶ Only used in accessible areas ▶ Requires skilled operators
Remarks	Vacuum trucks are preferred as they do not require much manual work. They are also more economical as they can transport large volumes of FS. However, many households in Dar es Salaam are not accessible by trucks and many cannot afford to pay for the large-scale emptying service.

2.4.3 Transfer stations

In Dar es Salaam it is under evaluation whether transfer stations can be used to collect and temporarily store FS before further transporting it to FSTPs or discharging it to the existing sewer network. The primary objective of the transfer stations is to provide localised FS storage capacity, enabling small-scale pit emptying operators to service households that normally are inaccessible to vacuum trucks, or which cannot afford to empty large volumes in one go. This is especially relevant where space for a full small-scale FSTP is not available near these households. Part of the approach is to use opportunities where particular transfer stations could provide an element of treatment as well as storage.

Potential options for transfer stations are:

- Underground (fixed) or mobile holding tanks with no treatment
- Fixed systems with partial treatment (liquid/solid separation) and/or connection to public sewer

The objective would be to reduce the cost for transportation to the FSTP. However, a good concept for the transfer stations needs to be developed jointly with key stakeholders. The risk of transfer stations is in the inappropriate operation of services which guarantee the conveyance of FS from the transfer station to the FSTP. Inappropriate operation of transfer stations leads to serious nuisance and hazards for local communities.

Figure 33 Implementation of a water distribution system - reusing the FSTP effluent for landscape irrigation in Mburahati

2.4.4 Treatment technologies

Objectives

According to CDD Society (2019), the objectives of FS treatment are:

- Dewatering
Easy handling and reduction of volume
- Pathogen inactivation
Safe handling and disposal
- Stabilisation
Decrease biological activity
- Nutrient management
Reuse and environmental protection

Technology selection planning and design

When designing an FSTP, consideration needs to be given to how to separate the solid and the liquid portion of the FS, and then how to stabilise the solids and how to treat the liquids. A general overview of the FS treatment process and guidance on selection of treatment technologies is presented in Figure 34.

The operation of an FSM system shall always be of the highest priority. It is essential to make O&M tasks as simple as possible. In addition, health and safety aspects need to be considered even in the early stages of system design and technology selection.

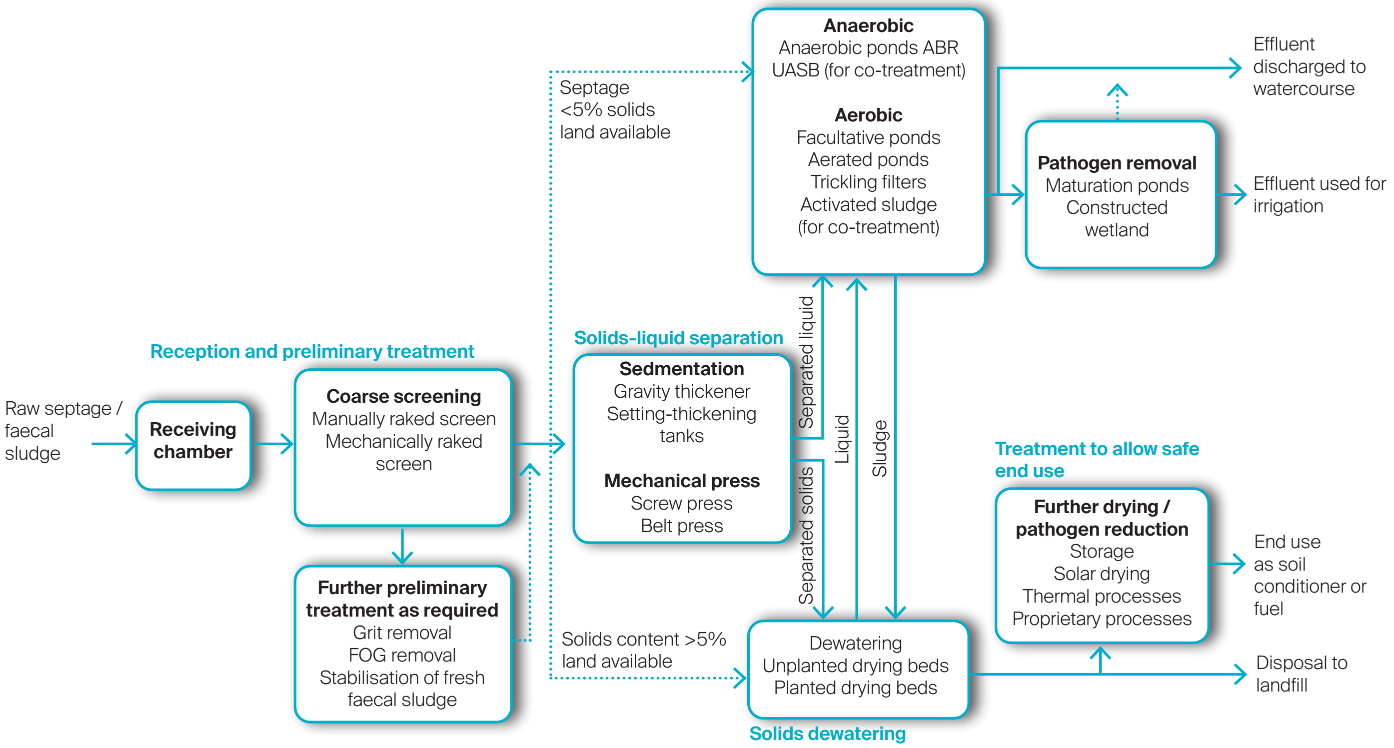


Figure 34 Schematic of various stages of FS treatment (adapted from Tayler, 2018)

The range of technologies being deployed globally for FS treatment has been steadily increasing over recent years, as demonstrated below in Table 18 and Table 19.

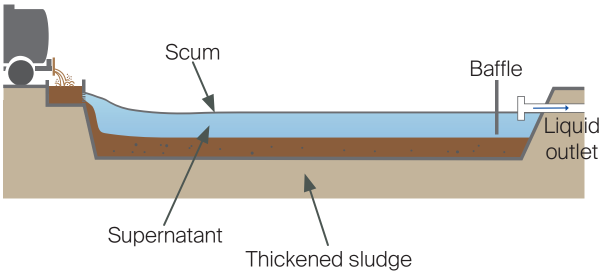
However, the anticipated list of technologies suitable for the small and medium FSTPs identified as appropriate within the current enabling environment of Dar es Salaam is a relatively small subset of the processes outlined below. These preselected technologies are listed and described in more details in the fact sheets below. The technologies eventually selected need to be determined through participatory approaches engaging all relevant stakeholders and based on detailed feasibility studies within the specific local context.

Process	Technology	Pro	Con
Receiving station	Screen	Protects the next treatment stage against grit, solid waste and grease	Additional operation task, disposal of the waste
	Sand trap		
	Grease trap		
Anaerobic stabilisation	Anaerobic stabilisation reactor (ASR)	Reduces odour, TS and thus the size of drying beds, biogas as by-product	Additional component with O&M requirement
	Biogas plant		
Gravity Solid-Liquid separation	Settler/thickener	Simple	Footprint
	Lamella separator	Simple	Not common
	Flocculation	Improves dewatering	High OPEX
Mechanical dewatering	Screw press	High capacity, small footprint	High CAPEX & OPEX, only for high capacities
	Centrifuge		
Natural dewatering and drying	Sludge drying bed	Simple	High footprint, monthly removal of sludge
	Solar enhanced drying bed	Very effective	High CAPEX & OPEX
	Planted drying bed	Simple, sanitised, biosolid as by-product	High footprint

Table 18 Available FS technologies associated with solids handling

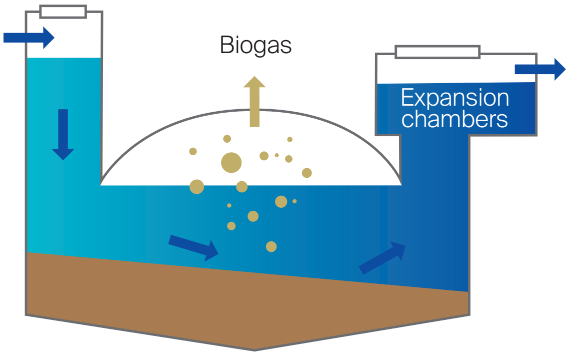
Process	Technology	Pro	Con
Thermal process	Omni process (combustion)	Small footprint, bio-fuel as by-product	Very high CAPEX & OPEX requires pre-treatment
	Pyrolysis		
Disinfection	Lime	Simple, low CAPEX	High OPEX
	Thermal processes	Effective	Very high CAPEX & OPEX
	Co-composting	Compost as by-product	High OPEX
	Pasteurisation	Small footprint, biogas can partly be used	Requires external energy source
	Chlorine	Simple, low CAPEX	High OPEX
	Planted drying bed	Simple, bio-solid as by-product in OPEX	High footprint
Effluent post-treatment	ABR	Simple	Only partial treatment
	AF	Simple	Only partial treatment
	PGF	Simple	Only partial treatment
	Aerated PGF	Effective	Power required
	Vertical sand filter	Very effective, low OPEX	High footprint
	Trickling filter	Small footprint, effective	Power required

Table 19 Available FS technologies associated with disinfection and effluent treatment

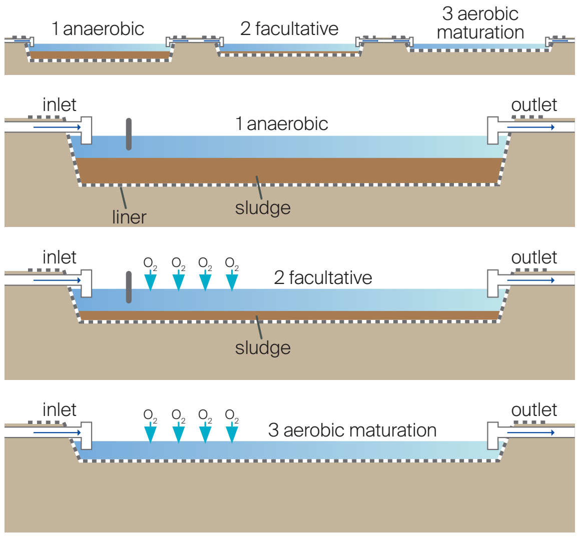


(Tilley et al., 2014)

Settling thickening ponds	
Purpose	Solids–liquid separation & partial stabilisation
Area required	HIGH
CAPEX	MEDIUM
OPEX	LOW
Strengths	▶ Good thickening performance ▶ No electrical energy required
Weaknesses	▶ High risk of odours and flies ▶ Long storage times ▶ Desludging requires adequate equipment
Remarks	Used when solids in the sludge have to be concentrated and to reduce the size of the dewatering units; sludge and effluent require further treatment.

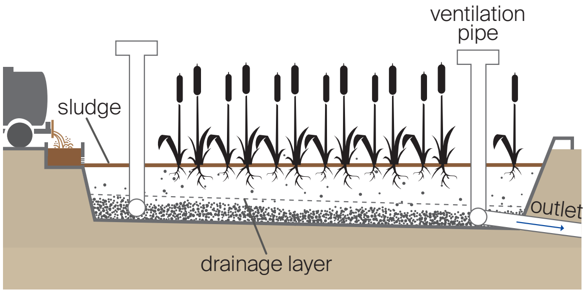


Anaerobic digestion (biogas settler)	
Purpose	Digestion and stabilisation
Area required	MEDIUM
CAPEX	MEDIUM
OPEX	LOW
Strengths	▶ No nuisance ▶ Biogas production ▶ Can be constructed underground ▶ No mechanical parts ▶ No electrical energy required ▶ Simple operation
Weaknesses	▶ If biogas is not used, it is a pollutant (greenhouse gas) ▶ Acceptance of using the biogas from FS is low ▶ Operators need to be trained to perform O&M adequately ▶ Requires skilled implementation ▶ Incomplete pathogen reduction
Remarks	Used when the organic load is high and helps in by-product recovery. Regular desludging must be performed to maintain treatment performance. The end use of the biogas shall be clearly defined before installing a biogas settler.



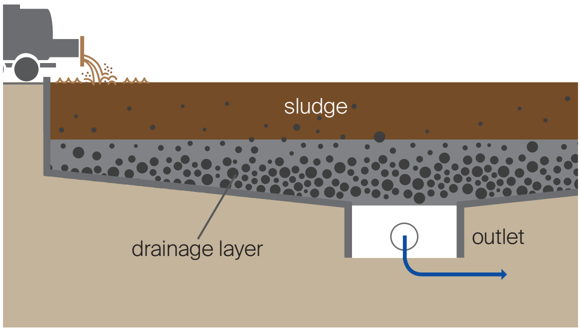
(Tilley et al., 2014)

Waste stabilisation ponds (WSPs)	
Purpose	Digestion and stabilisation
Area required	HIGH
CAPEX	MEDIUM (depends on the price of land)
OPEX	LOW (if desludging is not performed)
Strengths	▶ No electrical energy required ▶ Resistant to organic and hydraulic shock loads
Weaknesses	▶ If not designed and operated well, much nuisance ▶ Emission of greenhouse gases
Remarks	Frequent desludging is observed to be challenging (no costs allocated for this and no sludge treatment facilities available). Inadequate O&M is usually observed, leading to low performance and much nuisance.



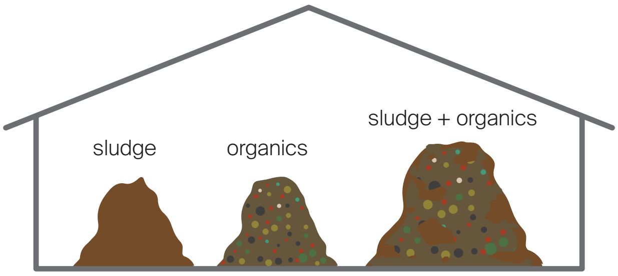
(Tilley et al., 2014)

Planted drying bed	
Purpose	Stabilisation and dewatering
Area required	HIGH
CAPEX	LOW (depending on price of land)
OPEX	LOW
Strengths	▶ Can handle high loads and load fluctuations ▶ Better sludge treatment than unplanted drying beds ▶ Low implementation and O&M requirements ▶ No electrical energy required
Weaknesses	▶ Odours and flies may be noticeable ▶ Long storage times ▶ Labour intensive removal
Remarks	Suitable for areas where there is no market potential for reuse & less complex treatment options are needed.



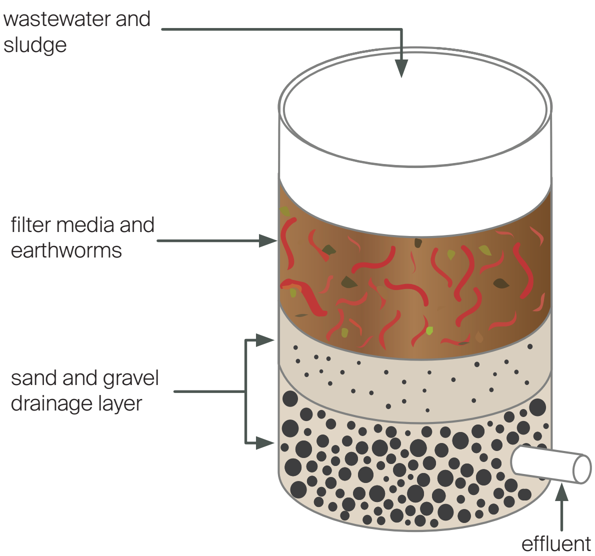
(Tilley et al., 2014)

Unplanted drying bed	
Purpose	Dewatering and partial stabilisation
Area required	MEDIUM
CAPEX	HIGH
OPEX	LOW (depending on price of land)
Strengths	▶ Good dewatering efficiency, especially in dry and hot climates ▶ Does not require electrical energy ▶ Low implementation and O&M requirements
Weaknesses	▶ High risk of odours and flies ▶ Labour intensive removal ▶ Limited stabilisation and pathogen reduction
Remarks	Suitable for areas where there is no market potential for reuse & less complex treatment options are needed.



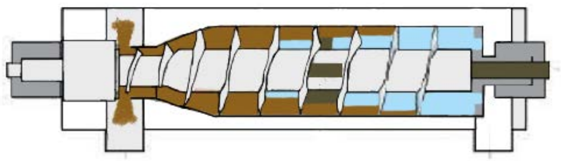
(Tilley et al., 2014)

Co-composting	
Purpose	Stabilisation and pathogen reduction
Area required	HIGH
CAPEX	LOW (depends on the price of land)
OPEX	LOW
Strengths	▶ Low requirements for implementation and O&M ▶ Valuable product (compost) ▶ Good stabilisation and pathogen reduction ▶ No electrical energy required
Weaknesses	▶ Labour intensive ▶ Can cause nuisances
Remarks	Useful in areas where organic material is available in adequate quantity and by-product value addition is possible.



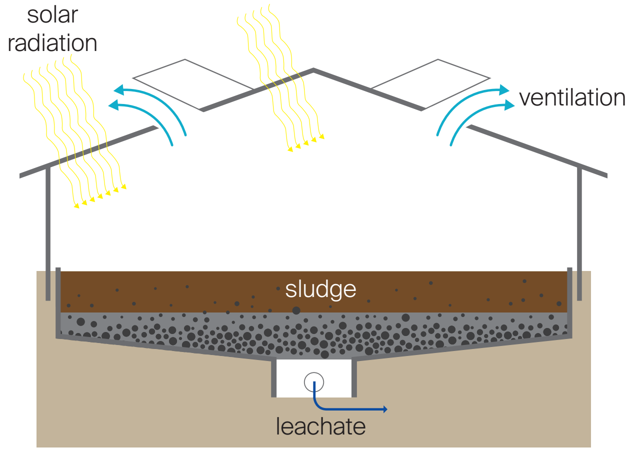
(Gensch et al., 2014)

Worm-based systems (vermicomposting)	
Purpose	Stabilisation, and reduction of pathogens and volume
Area required	HIGH
CAPEX	LOW
OPEX	LOW
Strengths	▶ High quality of end product (compost) ▶ High reduction of FS volume ▶ High reduction of contaminates ▶ Low requirement for implementation and O&M
Weaknesses	▶ Labour intensive ▶ Can cause nuisances
Remarks	Worms (e.g. earthworms or tiger worms) are sometimes difficult to obtain.



Decanter

Mechanical dewatering e.g. screw press & decanter	
Purpose	Solid-liquid separation and reduction of sludge volume
Area required	LOW
CAPEX	HIGH
OPEX	HIGH
Strengths	▶ High performance for solid-liquid separation ▶ High reduction of FS volume
Weaknesses	▶ Limited experience in design, operation and maintenance ▶ Requires electrical energy and cannot be manufactured locally ▶ Addition of conditioners
Remarks	Useful in presence of sustainable and reliable source of power.



Solar drying	
Purpose	Reduction of volume, moisture and path-ogens
Area required	HIGH
CAPEX	LOW
OPEX	LOW
Strengths	▶ Low investment and operating costs ▶ Medium reduction of sludge volume ▶ Medium reduction of pathogens
Weaknesses	▶ Limited experience in design, opera-tion and maintenance ▶ Can require mechanical equipment and electrical energy for ventilation and turning of FS
Remarks	Ventilation (e.g. by fans) and regular turning of FS increase the potential for evaporation.

Figure 35 Solid waste accumulated at FSTP>

Liquid treatment technologies

The treatment of the liquid portion of FS is not discussed in depth in this guide, as it is similar to the treatment of wastewater. A Tanzanian guide for decentralised wastewater treatment was published by the MoW in 2018. An overview of treatment processes for the liquid portion is pictured in Figure 36 below. The combination of treatment modules mainly depends on the targeted effluent quality and the availability of space.

Note that the liquid portion of FS usually contains a high concentration of COD and biologically difficult-to-degrade substances. This is because FS has a long retention time in containment systems before reaching the FSTP. In contrast, wastewater is directly conveyed to the WWTP and thus basically no biological degradation takes place before the wastewater enters the WWTP.

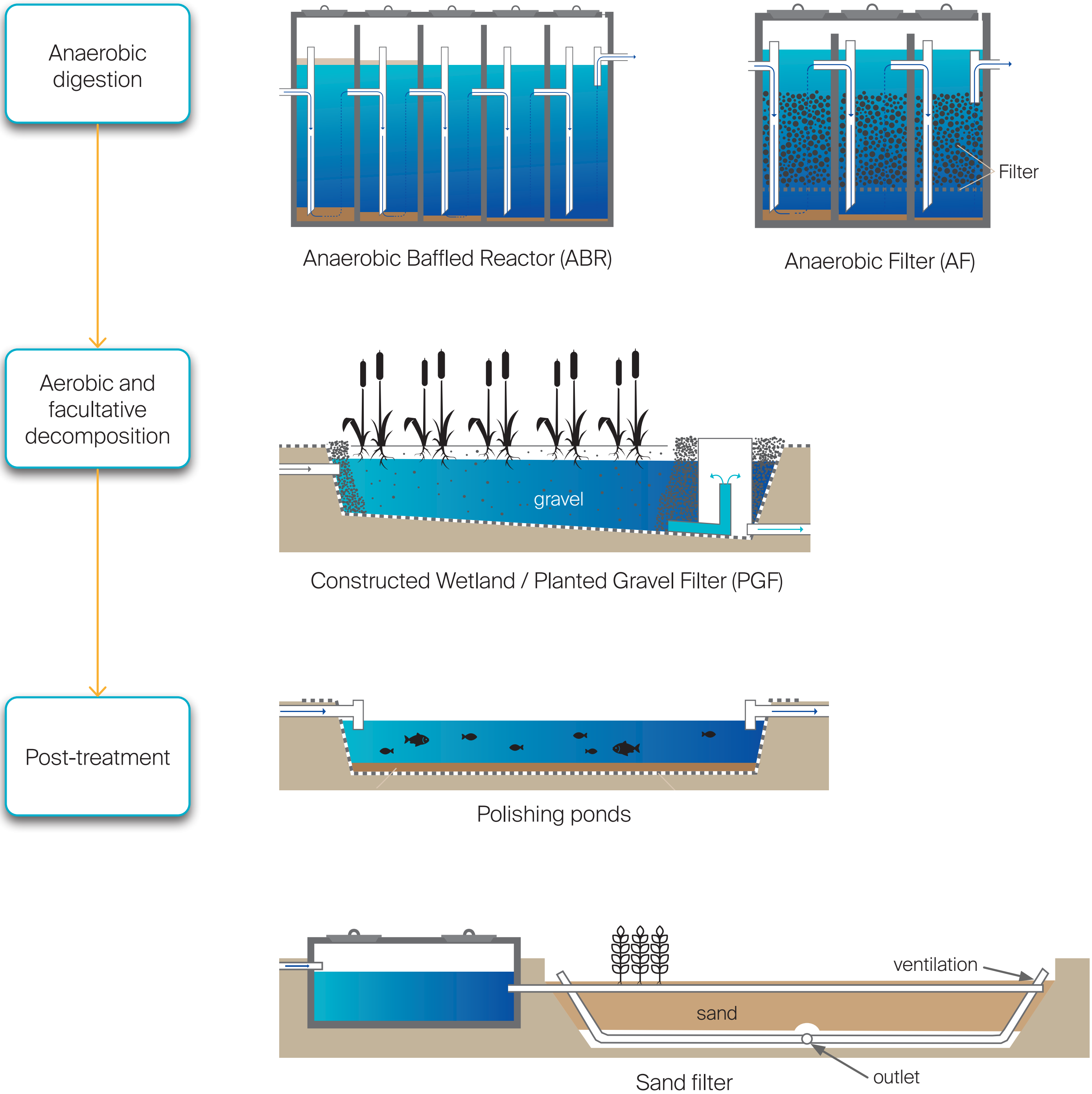


Figure 36 Overview of the treatment process for the liquid portion of FS in an FSTP

Figure 37 Removal of solid waste before emptying service with trash pump and appropriate PPE>


UKaid
HDIF

2.4.3 Advanced treatment, product development, reuse and safe disposal

Reusing and safely disposing of faecal sludge in Tanzania is of growing importance. According to the FAO (2021), agriculture is 26.7% of the nations GDP and employs approximately 80% of its population. Consisting mostly of small-scale farmers with limited access to fertiliser and improved seeds, yield is low and farmers are dependent on rain-fed production. With a rapidly growing population and an increasing demand for limited resources, water stress will continue to grow as well as the need for treated FS and wastewater that can be used for agricultural purposes.

In the use of treated FS, hazardous components need to be controlled and taken into account. These components can include pathogens, chemical contaminants such as heavy metals and pharmaceutical compounds and solid waste (Table 20). Furthermore, overloading natural water courseways with effluent from FSTPs causes eutrophication and is harmful for the health of the local ecosystem.
When properly treated, the by-product of FSM can become an additional revenue stream and add to the practicality of the business model. This requires planning the treatment according to the end use, ensuring public and environmental health while not "over treating". Each additional treatment is related to increased costs (CAPEX and OPEX) and conventionally also to increased space requirements.

Technologies for additional treatment

Their are five typical technologies to further treat FS: storage for an extended period, composting, lime stabilisation, infrared radiation, and thermophilic biodigestion. Additionally, thermal drying and pyrolosis effectively destroy pathogens while also preparing the biosolids for fuel, although these technologies require external energy inputs. Biogas digesters typically operate in the mesophilic range and don't adequately kill pathogens, requiring an extended period of storage and drying.

Extended storage and drying is the simplest method of killing pathogens, however this could require large amounts of space and long periods of storage depending on temperature,

Input flows	Composition of input flows	Output
As per design: **Blackwater** ▶ Excreta ▶ Urine ▶ Faeces **Brown water** ▶ Faeces ▶ Flushwater ▶ Anal cleansing water ▶ Dry cleansing material **Greywater** ▶ Shower ▶ handwashing ▶ kitchen ▶ laundry To be avoided: **Solid waste** ▶ Hygiene products ▶ Organics ▶ Plastic bags, batteries, etc. ▶ Ash **Stormwater and groundwater** **Salt and petroleum** **Industrial wastewater**	Beneficiary resources: ▶ Water ▶ Organic matter ▶ Nutrients (nitrogen (N), phosphorus (P) and potassium (K)) ▶ Sand ▶ Grit Challenging contaminants: ▶ Pathogens (helminths, bacteria, viruses and protozoa) ▶ Chemical contaminants (e.g. pharmaceutical compounds, heavy metals, dyes, surfactants or pesticides) ▶ Solid waste (e.g. plastics or metals)	Products: **Liquid fertiliser:** ▶ Stored urine, concentrated urine, sanitised blackwater, digestate, nutrient solutions **Solid fertilisers:** ▶ Dry urine, struvite **Soil conditioners:** ▶ Dried faeces, pit humus, dewatered sludge, compost, ash from sludge, biochar, nutrient-enriched filter material **Biomass and proteins:** ▶ Algae, macrophytes, black soldier fly larvae, worms **Water:** ▶ Irrigation water, aquaculture **Energy:** ▶ Biogas, solid fuels (e.g. pellets or briquettes) Residuals for safe disposal: ▶ Liquid -> infiltration, evapotranspiration and/or discharge ▶ Solids -> incineration and/or landfill

Table 20 Composition of input flows and potential outputs

moisture and other conditions.
There is a growing list of treatment technologies, some of which are listed in Figure 38, each with their own strengths and weaknesses that will not be discussed in detail here. Further information can be found in the supporting literature box.

Safe reuse and disposal

The approach to reduce the hazard of poorly or untreated FS is a multi-barrier approach to reduce the exposure to humans (sanitation workers, community members and consumers) while also reducing the impact on the environment. This requires proper PPE, good hygiene behaviours, physical barriers around treatment facilities and irrigation buffer zones to safeguard the community from direct contact. Most common current technologies do not reduce nutrients (Nitrogen and Phosphorous) and do not disinfect. This is not problematic if the exposure to humans and the impact on the environment are controlled. Crops that avoid direct contact with the treated sludge should be chosen to avoid the ingestion of still active pathogens, such as banana or other fruit-bearing trees.

Discharge to inland surface water bodies requires reduction of nutrients (nitrification and denitrification, and reduction of phosphorus), and disinfection to avoid eutrophication and reduce the impact on the environment.

Acceptance

The acceptance of FS and its reuse is heavily dependent on the acceptance by its users, both farmers and consumers. Acceptance can vary based on a variety of cognitive, psychological, religious or cultural reasons and must be addressed with a combination of demonstrations, early adoption, subsidies and education.

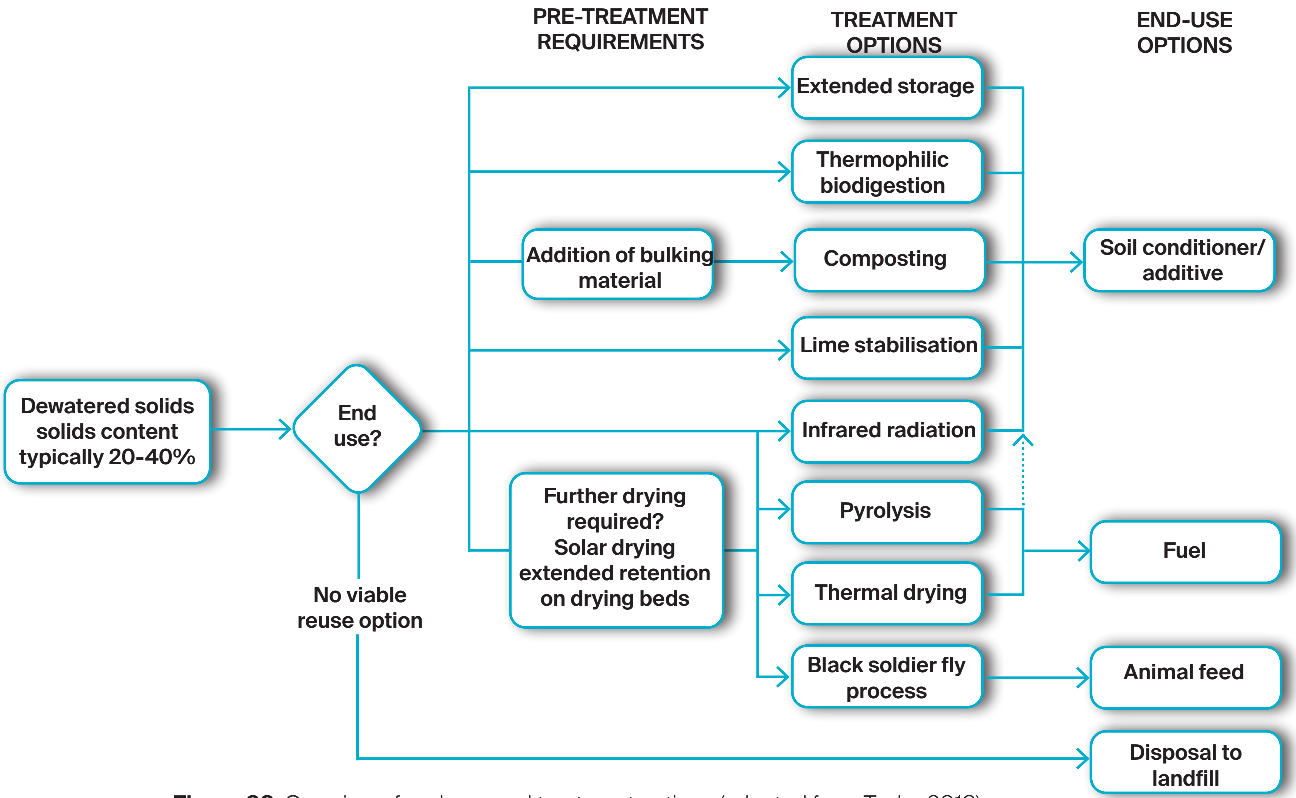


Figure 38 Overview of end-use and treatment options (adapted from Tayler 2018)

Supporting literature

- FAO (2021). Tanzania at a Glance.
- McConville et al. (2020). Guide to Sanitation Resource Recovery Products & Technologies
- Strande et al. (Eds.) (2014). Faecal Sludge Management: Systems Approach for Implementation and Operation.
- Tayler (2018). Faecal Sludge and Septage Treatment: A guide for low- and middle-income countries.
- Tilley, et al. (2014). Compendium of Sanitation Systems and Technologies.
- World Health Organization (2018). Guidelines on sanitation and health.

3. FSM CASE STUDIES

3.1 Baseline survey for FSM intervention

3.1.1 Introduction

The baseline survey was conducted by Ifakara Health Institute (IHI) in two sub-wards, Mburahati Barafu and Miburani, from December 2017 to May 2018 and July to November 2018, respectively. 412 households in Mburahati Barafu and 398 in Miburani were selected randomly. The baseline survey had a total of 64 questions, with 20 questions related to sanitation practices and DEWATS usage. The criteria for selecting interviewees considered residents older than 17 who had lived in that area for at least 6 months. The analysis aimed to identify the number of households using OSS and their respective emptying frequency. This data will be used in future projections for emptying service demand.

3.1.2 Findings and discussion

The survey revealed that 82% of households in Mburahati and 80% in Miburani use OSS, which points to the need for E&T services. For each sub-ward, Table 20 below details the percentage of OSS, the emptying frequency, and the households that never emptied their toilet.

70% of respondents in Mburahati Barafu and 40% in Miburani reported never having emptied their latrine, which may be related to accessibility of the latrine or cost of service. Analysis of household vehicle access in typical wet or dry seasons and willingness to pay (WTP) revealed some correlation to the practice of emptying the latrine. Figure 38 below presents household accessibility in the two areas.

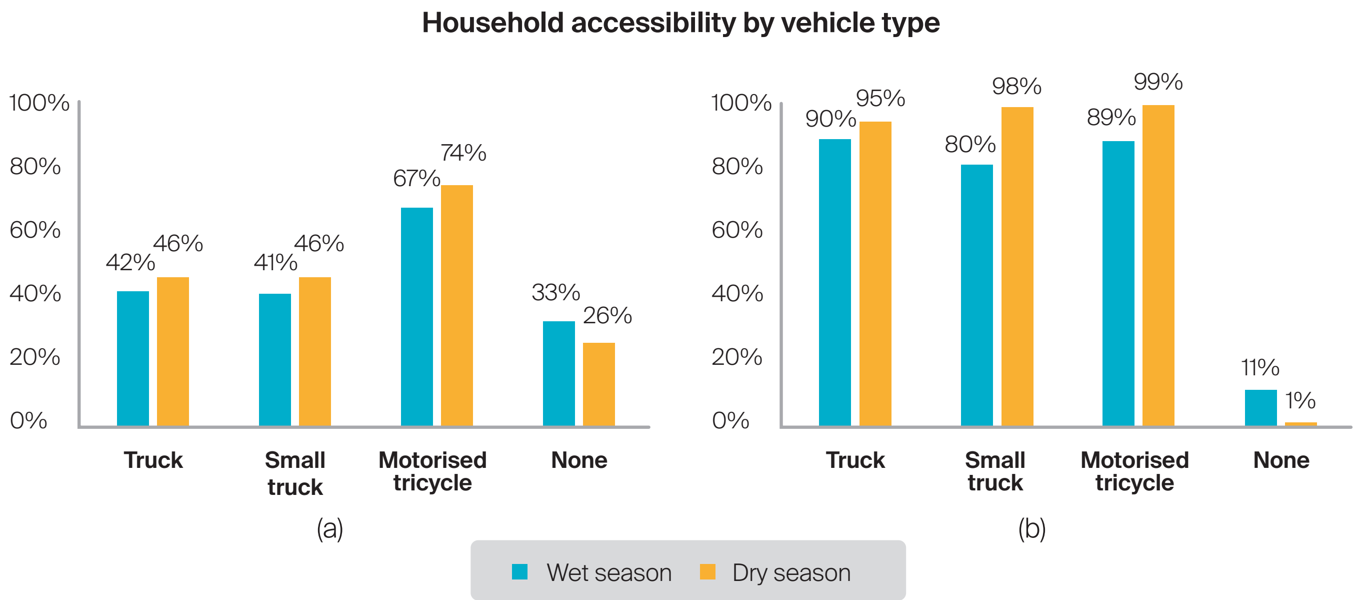


Figure 39 Mburahati (a) and Miburani (b) household accessibility

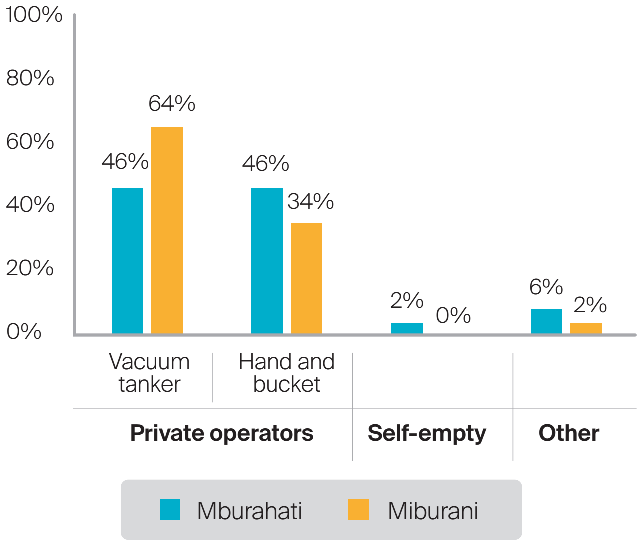
Sub-ward	On-site sanitation			Frequency of emptying/year	% Never emptied
	% Total	% Pit latrines	% Septic tanks		
Mburahati	82	57	25	2	70
Miburani	80	17	63	2	40

Table 21 Details of OSS and emptying frequency in Mburahati & Miburani sub-wards

Figure 40 <Emptying service with vacuum truck in Ubungo, Dar es Salaam

Figure 40 below summarises the method that people in Mburahati and Miburani use for emptying.

In both areas, most of the respondents who emptied their latrines paid for the service in cash (93% in Mburahati and 81% in Miburani). Depending on the income of the family, there was a variation in the amount paid for the last emptying service. Table 21 below shows that in Mburahati, the majority of the respondents paid an average of 35,000 TZS (≈15 USD) for 5m^3, which is only 50% of the amount paid in Miburani for a truck with the same capacity.



The 'other' method of emptying implies that the individual may not be willing to admit they empty illegally.

The observation indicates a significant variation between the types of services (mechanical and manual) depending on the location.

Figure 41 Methods for pit emptying used in Mburahati and Miburani

Sub-ward	Respondents (%)	Truck capacity (m^3)	Service price (TZS)		Average cost (TZS)	Average cost/1 m^3
			Minimum	Maximum		
Miburani	65	05	40,000	100,000	70,000	14,000
	26	08	110,000	160,000	135,000	16,875
	09	10	165,000	230,000	197,000	19,750
Mburahati	73	05	20,000	50,000	35,000	7,000
	06	08	55,000	110,000	82,500	20,500
	03	10	120,000	200,000	160,000	32,000

Table 22 Emptying service charge in Mburahati and Miburani

The survey also looked at the willingness of the communities in Mburahati and Miburani to pay (WTP) for the emptying services. The majority of the respondents (88% in Miburani and 60% in Mburahati) reported that they are willing to pay for the service. Table 22 shows the response related to the amount households are willing to pay for E&T services.

Going further, the survey looked into the factors associated with WTP for the services. For both study sites, a large number of female respondents were willing to pay for the service compared to male participants. However, it was observed that male respondents were willing to pay 13,000 TZS more than female respondents were. Additionally, participants with secondary and college education were willing to pay 9,000 TZS and 6,000 TZS more than those who were not educated. Households with better income were willing to pay 5,000 TZS more than lower income households. Furthermore, participants who owned businesses were willing to pay 6,000 TZS more than those who were employed.

Sub-ward	Respond-ents (%)	Truck capacity (m^3)	Service price (TZS)		Average cost (TZS)	Average cost/1m^3
			Minimum	Minimum		
Miburani	70	5	40,000	80,000	60,000	12,000
	18	8	90,000	130,000	110,000	13,750
Mburahati	55	5	30,000	50,000	40,000	8,000
	5	8	55,000	80,000	67,500	8,438

Table 23 Willingness to pay emptying service charge in Mburahati and Miburani

3.1.3 Conclusion

The baseline study revealed the existence of poor sanitation management due to poorly designed and constructed sanitation systems that are unable to offer proper sanitation services. The high cost of emptying services and a lack of law enforcement result in people opting for unhygienic emptying practices.

The study showed that 65% of the respondents in Mburahati paid 70,000 TZS and 73% in Miburani paid 53,000 TZS for the emptying service using a 5m^3 truck. This variation might be due to differences in study areas. There is no significant difference between the average amount of money paid for the last emptying in Mburahati (53,000 TZS) and Miburani (70,000 TZS) compared to the amount that they are willing to pay for the emptying (40,000 TZS and 60,000 TZS, respectively). This shows households have an interest in paying for the emptying service, and would even pay more than the existing fee.

The study reveals that the gender of household heads (males, as they have decision-making power) and the household income level as well as the educational status of the family head had statistically significant associations with the WTP.

3.2 Decentralised FSTPs in Dar es Salaam

BORDA Tanzania in collaboration with other development partners, local NGOs and DAWASA has established four FSTPs in four municipalities of Dar es Salaam (Kinondoni, Ubungo, Kigamboni and Temeke). The four FSTPs are in operation and receive a total of 30m^3 of FS per day, serving about 90,000 people.

The major challenges during the planning phase were land acquisition and community acceptance. Awareness campaigns involving training, sanitation bazaars and exposure visits to existing FSTPs were key for the community to understand the need for the new FSTPs and build a sense of project ownership.

BORDA together with partners established a steering committee with the task of overseeing successfully operation and maintenance of each FSTP. The committee has collective tasks and defines the role of each stakeholder in the group. The main members of the steering committees are the municipality, community representatives, BORDA and DAWASA.

Figure 42 Unplanted drying bed at Mburahati-Ubungo FSTP

3.2.1 Tungi-Kigamboni FSTP

Project background

The first Tanzanian small-scale FSTP following the DEWATS approach was implemented by BORDA in 2012/2013 in Tungi-Kigamboni, Dar es Salaam, in cooperation with the sanitation entrepreneur Mr. Mathias Millinga. Mr. Millinga was active in solid waste collection and also operated a small transfer station for FS. He collected FS in small volumes (app. 1m^3 per trip) and stored it on his private land. When the storage was full, he called vacuum trucks to collect the FS. The unit cost for the small-volume collection service was higher than the large-scale vacuum truck. The balance was his income and enabled the business.

BORDA supported this business by building an FSTP on Mr. Milinga's private land. Thus, Mr. Millinga no longer needed to pay for the vacuum truck to empty his transfer station, but could treat the FS on his own site. In addition, he could utilise the generated by-products: biogas (for cooking), water (for irrigation) and treated sludge (as soil conditioner). See the financial flow model in Figure 42.

The objectives of installing the FSTP were to treat FS and also to establish a learning and research center. On June 16th, 2016 the Kigamboni Training Centre was inaugurated. Since then, many national and international sanitation stakeholders have visited the site and obtained an improved understanding of FSM.

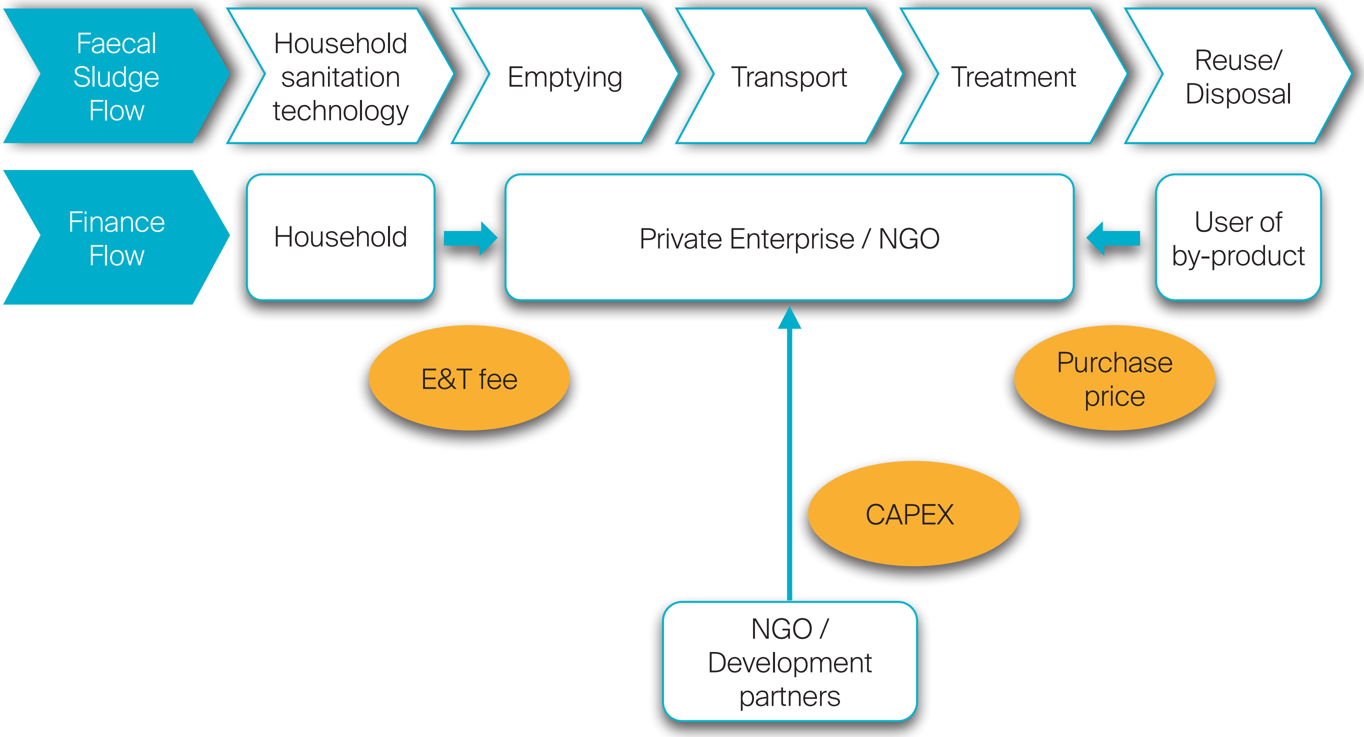


Figure 43 Financial flow model for small-scale FSM service in Tungi-Kigamboni

Lessons learnt

Major successes:

- The FSTP has been operating sustainably since 2013, with no major maintenance required.
- Treatment efficiency is good, and the effluent quality is appropriate for irrigation of crops (e.g. banana, maize or papaya).
- The service provider is very well integrated in and recognised by the community. This helped in creating demand and acceptance for the service.
- The service provider lives at the site, and thus the FSTP is always under observation and there is always a contact person at the site.
- The combination of several businesses (e.g. FSM and solid waste) enables cost recovery.
- The training and demonstration site capacitates national and international sanitation stakeholders from diverse backgrounds, and has achieved recognition for small-scale and decentralised FSM as a sustainable solution.

Major challenges:

- Since the FSTP is on private land, the institutional set-up for monitoring performance by national regulatory authorities is not clear. It all depends on the landowner and business operator to ensure that the system is performing according to environmental regulations.
- Limited treatment capacity (5m^3/day) limits the growth of the FSM business.
- There are shock loads due to no buffer (feeding tank) at the inlet of the FSTP.
- Sourcing financing to upscale the business is challenging, as few financial institutions are willing to invest in the venture due to the lack of a proven business model for running such a small-scale FSTP.

Figure 44 Motorised tricycle at the Tungi-Kigamboni FSTP

Figure 45 Discharging FS at the Tungi-Kigamboni FSTP with the SludgeGo

Tungi-Kigamboni FSTP Fact Sheet	
Objective	Sludge disposal with FS treatment
Location	Kigamboni, Dar es Salaam, Tanzania
Role of BORDA	Design, construction and monitoring
Implementing partners	BORDA
Funded by	BMZ
Construction period	Dec 2012 – May 2013
Construction cost (materials & labour)	Approx. 40,000,000TZS
Type of construction	Concrete, brick & block work
Project status	In operation since June 2013
FS source	Pit emptying business from household
Amount of FS	5 m^3/d
No of beneficiaries	≈ 15,000 people
Effluent quality	BOD≈90mg/l, COD≈180mg/l
Reuse of effluent	Gardening
System layout	840m^2 (total area)
▶ Biogas settler	50m^3
▶ ABR	12m^3
▶ Sludge drying bed	50m^2
▶ Vertical sand filters	12m^2

Table 24 Tungi-Kigamboni FSTP fact sheet

3.2.2 Mlalakuwa-Kinondoni FSTP

Project background

The implementation of the FSTP in Mlalakuwa (Makongo, Dar es Salaam) was part of a project in 2015, which was a joint initiative of BORDA and GIZ to restore the Mlalakuwa River to an environmentally good condition. Major risks for the environment and public health were caused by households at the river banks that illegally dumped FS and wastewater into the river. From an FSM perspective, the project had the objective of replicating the Kigamboni pilot FSM system, aiming to prepare for scaling up small-scale decentralised FSM in Dar es Salaam.

From a technology perspective, the FSTP and the E&T equipment implemented in Mlalakuwa are almost identical to the ones in Tungi-Kigamboni (see Figure 45). The FSTP follows the DEWATS approach. The FSTP was constructed on military land (public land) close to the community. The innovative approach of this FSTP was its institutional arrangement, with a steering committee as project coordinator, a private entrepreneur who provides the E&T service and operates the FSTP, and BORDA as technical backup for maintenance services (Figure 45). The setup was adapted after two more FSTPs were implemented, and all three FSTPs could be operated jointly from January 2019.

The Mlalakuwa FSTP was implemented jointly with awareness creation and social marketing campaigns. Specific approaches to create demand for sanitation services were developed and tested in Mlalakuwa, and later in Mburahati and Miburani. The costs for social interventions are not included in the construction costs mentioned below.

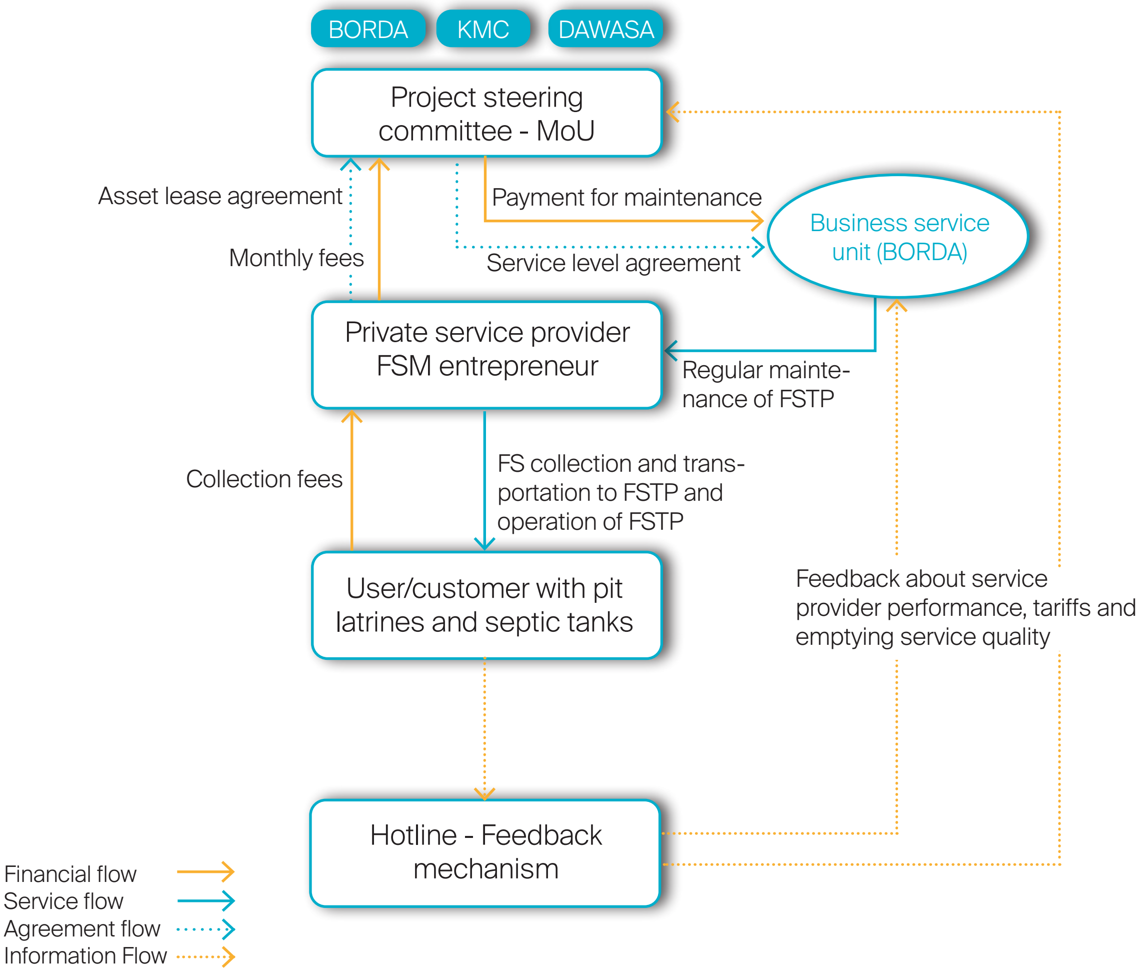


Figure 46 Mlalakuwa project organisation and activities


WANHOO

Lessons learnt

Major successes:

- ▶ The establishment of a steering committee to supervise the operation of the plant (comprising of DAWASA/DAWASCO, Kinondoni Municipal Council (KMC), BORDA and the sub-ward office) was an effective measure to bridge the gap created by unclear formal institutional arrangements for small-scale decentralised FSM.
- ▶ Awareness creation, behaviour change and marketing campaigns were conducted to promote FS emptying service and create demand in Mlalakuwa. Effective interventions included the public event for plant inauguration, the Cleanest Community competition, door-to-door marketing, and loudspeaker information and promotion campaigns.
- ▶ Acceptance of the FSTP by the neighbouring household is increased by letting this household benefit from the by-products: biogas and bananas (which are grown using the treated wastewater).

Major challenges:

- ▶ Outsourcing a service provider to operate the plant was challenging.
    - There were few/no service providers who had E&T equipment or capital to purchase equipment. Only a few service providers had sufficient experience to provide FSM service.
    - Most potential service providers were not convinced of the business case.
    - The willing operator who had the requisite experience and tools to run the plant found it not economical to operate from his location unless with considerable demand which put clients on long waiting lists.
- ▶ Lack of E&T fee tariffs made it difficult to assess the affordability of the service and create demand. Willingness and/or ability to pay for the service was lower than the expenditures for its provision (OPEX).
- ▶ The plant's treatment capacity ($5m^3/d$) is too small to enable efficient FSM services and to recover operating costs.
- ▶ The plant's proximity to residences has led to frequent complaints.

Mlalakuwa-Kinondoni FSTP Fact Sheet	
Objective	To improve community FSM through sustainable cost-recovery model for service provider and operation of FSTP
Location	Mlalakuwa sub-ward, Makongo ward
Role of BORDA	Design, construction & monitoring
Implementing partners	Kinondoni Municipal Council, KMC, DAWASA/DAWASCO and BORDA
Funded by	GIZ (among others)
Construction period	Jul 2016 - Jan 2017
Construction costs	~ 25,000,000TZS
Main project activities	▶ Establishment of business model for FSM ▶ Institutional set-up (steering committee comprising key stake-holders from KMC, BORDA and DAWASA/DAWASCO) ▶ Awareness campaign for FSM to trigger service demand ▶ FSTP management set-up which includes contracting service provider through tendering procedure ▶ Capacitate service provider on cost-recovery management and O&M

Table 25 Mlalakuwa-Kinondoni FSTP fact sheet

Figure 47 <Discharging at Mburahati-Ubungo FSTP with motorised tricycle

3.2.3 Mburahati-Ubungo and Miburani-Temeke FSTPs

Project background

These two FSTPs were constructed in communities characterised by low incomes, high population density, and no sewerage connections to the centralised network. In addition to the FSTPs, BORDA established and tested an FSM service provision model which enables hygienic and efficient E&T services. The service model put in place was decentralised treatment in combination with centralised management. The two newly constructed FSTPs were operated jointly with the FSTP in Mlalakuwa.

FS was emptied and transported by two sets of equipment, which were utilised according to demand:

- Small scale: mud pump, trash pump or eVac, in combination with a motorised tricycle (max. $1m^3$ per trip)
- Medium scale: a $3.7m^3$ vacuum truck

Effluent of the FSTP is used to irrigate (1) the vegetation around the perimeter of the site as well as trees which will be planted around the adjacent football field to improve the immediate urban surroundings at Mburahati, and (2) a banana plantation at Miburani.

Figure 48 FSTP at Miburani-Temeke

Figure 49 Construction of Biogas Settler

Miburani-Temeke FSTP Fact Sheet	
Objective	Replication of FSM approach and testing of cost recovery models
Location	Dar es Salaam, Tanzania
Role of BORDA	Design, construction, O&M, and monitoring
Implementing partners	BORDA, IHI & TMC
Funded by	HDIF/UK-Aid
Construction period	May–Sep 2018
Construction cost (materials & labour)	≈ 120,000,000TZS
Type of construction	Concrete, brick and block works
Amount of FS	≈ $10m^3/d$
No of beneficiaries	≈ 30,000 people
System layout	$840m^2$ (total area)
▶ Ramp	$150m^2$
▶ Feeding tank	$10m^3$
▶ Biogas settler	$50m^3$
▶ ABR	$24m^3$
▶ Sludge drying beds	$25m^2$
▶ Office, store & toilet	$27m^2$
▶ Banana plantation	$240m^2$

Table 26 Miburani-Temeke FSTP fact sheet

Figure 50 FSTP at Mburahati-Ubungo

Figure 51 Construction of ABR, AF and Biogas Settler at Mburahati-Ubungo FSTP

Mburahati-Ubungo FSTP Fact Sheet	
Objective	Replication of FSM approach and testing of cost recovery models
Location	Mburahati, Barafu (Ubungo, Dar es Salaam)
Role of BORDA	Design, construction, O&M, and monitoring
Implementing partners	BORDA, IHI, UMC & OSWAMS
Funded by	HDIF/UK-Aid
Construction period	Nov 2017 - Feb 2018
Construction cost (materials & labour)	~ 150,000,000TZS
Type of construction	Concrete, brick and block works
Amount of FS	≈ 10m^3/d
No of beneficiaries	≈ 30,000 people
System layout	415m^2 (total area)
▶ Ramp	50m^2
▶ Feeding tank	10m^3
▶ Biogas settler	50m^3
▶ ABR	22m^3
▶ Sludge drying beds	25m^2
▶ Office, store & toilet	27m^2
▶ Banana plantation	191m^2

Table 27 Mburahati-Ubungo FSTP fact sheet

Figure 52 Site visit of key stakeholders during construction of the biogas settler

The Innovation

The 'DEWATS for Dar' project established small-scale decentralised FSM services that are customised to the needs and challenges of communities in unplanned, low-income settlements of Dar es Salaam; providing safe and professional solutions to households that would otherwise have no access to adequate pit emptying services. The established sanitation system and services focus primarily on the following components of the FSM value chain - emptying, transportation, treatment and reuse or final disposal.

The Innovation: Emptying & Transportation
The 'eVAC' (a motorised vacuum system) and trash pump are being used for pit emptying, in combination with a small tricycle. A small-vacuum truck is used to serve accessible households. A combination of these innovative technologies provide affordable and professional services to even the most inaccessible households. Residents in the project areas explained that private vacuum trucks usually charge between 70,000TZS - 100,000TZS (≈$25USD - $43USD). But the new service was offered for 50,000 TZS (≈$18USD) for the same volume of app. 3m^3 to be emptied.

The Innovation: Treatment
The small-scale FSTPs (5-10m^3 per day) with minimal operational requirement (no electrical energy, chemicals, nor complex mechanical equipment) treat the liquid fraction of FS to a standard, which is safe for infiltration into the ground, or for reuse with subsurface irrigation systems.
Additionally these FSTPs can be constructed and operated using locally available resources and local artisans, resulting in robustness of the system, and reasonable CAPEX and low OPEX. The systems are constructed underground on small pieces of land, meaning that they can be integrated into densely populated urban communities – reducing the negative impact on the surrounding environment (e.g. in comparison to large, open WSPs).

The Innovation: Reuse or final disposal
Additional benefits are obtained by the generation of by-products, such as biogas for cooking and effluent water that is reused for irrigation in landscaping and gardening (banana plantations and trees).

The Innovation: Cost recovery model
The cost recovery model for FSM consists of E&T services and management of the FSTP by a small private sector entity. Service fees are collected at the household level, for E&T services conducted by the operators employed by the private entity. The fees help to recover operational expenses, by paying for operator salaries, and maintenance of the equipment and vehicles. In the long-term arrangements, the FSTPs are owned and maintained by the public utility.

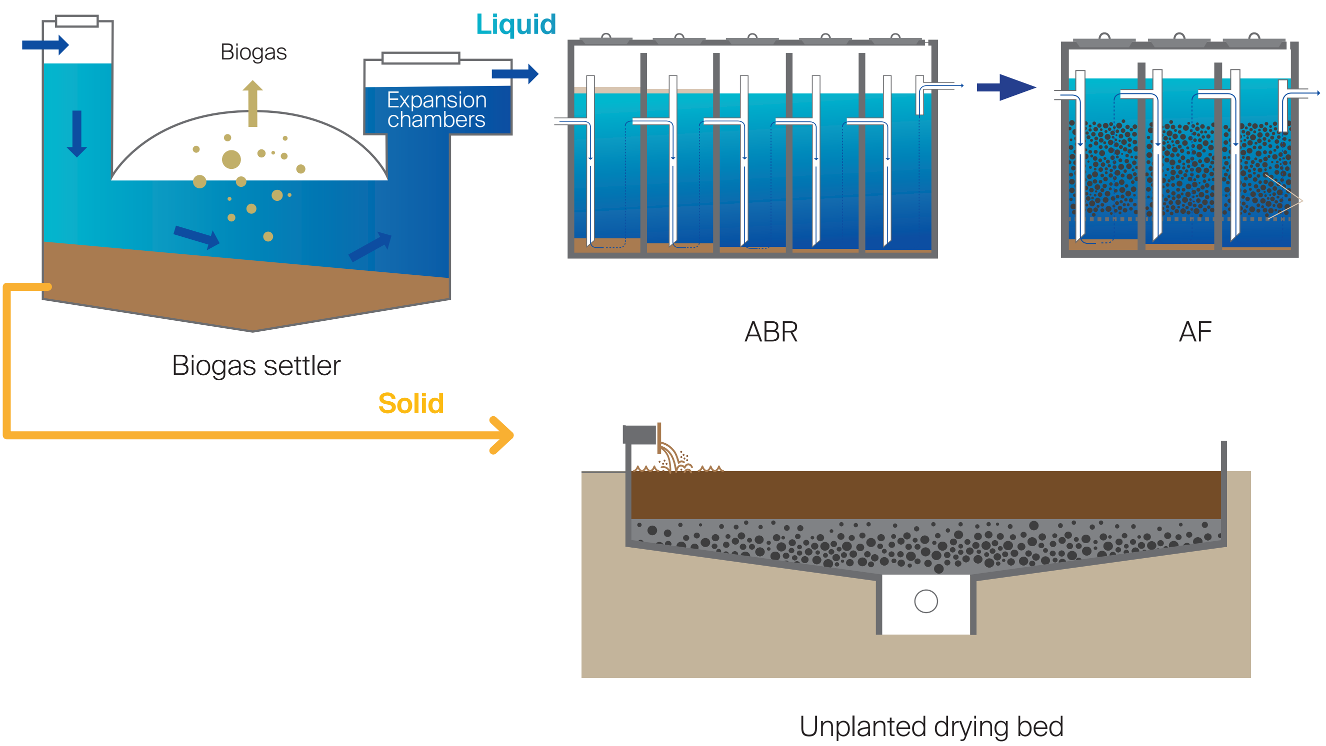


Figure 53 FSTP treatment modules

The aims was to achieve cost recovery and sustainability across the FSM value chain and at the same time enabling affordable solutions to households. Recovering costs from the sale of by-products was evaluated, but did not prove to be significant. Thus, by-products are to be perceived as additional benefits for the operators and the community, increasing the acceptance of the system.

The Innovation: Partnerships with stakeholders

A major success of the project is the awareness about and acceptance of decentralised FSM. This was developed by continuous engagement of public and private sector stakeholders. National and international knowledge exchange initiatives including presentations at a variety of conferences, and organising visits for stakeholders from relevant institutions to the sites at different stages of implementation and operation were facilitated.

A steering committee consisting of representatives of DAWASA, LGAs, the community representative and BORDA was a successful tool to bridge the gap in the institutional arrangements and legal frameworks for this innovative approach. The steering committee was especially helpful for resolving challenges and to create consensus among the different key stakeholders. During the start-up phase, BORDA was given the mandate to centrally operate and maintain all three FSTPs before handing them over. The steering committee also agreed, that according to the new legislation (2019 WSS Act) the FSTPs and the equipment for O&M is to be handed over to DAWASA.

The Innovation: Education, awareness, marketing and community engagement

These were provided to enabled the implementation, O&M and handover of the FSM system. The topics included:

- Latrine cleaning and personal hygiene (e.g. handwashing, proper use of toilets)
- Solid waste and menstrual hygiene management
- Environmental benefits of FSM and the household responsibilities to achieve improved environmental conditions (e.g. the importance of paying for E&T and solid-waste collection services; the benefits of constructing pits and slabs which enable easy removal of FS; and the benefits of constructing safe and private toilet superstructures, with regular cleaning).

The project success was strengthened through public awareness creation and marketing campaigns. Awareness creation was conducted in the form of community general assemblies, focus group discussions, workshops, training, community sanitation exhibitions, poster installations and a sanitation bonanza. A public marketing campaign was undertaken to promote sanitation behaviour change and the FSM services. This campaign was in the form of radio announcements; posters installed at local government offices and other public places; loud-speaker messages announced while driving through the communities; and door-to-door visits and distribution of brochures.

Figure 54 Service providers discharging sludge into Mburahati - Ubungo FSTP

Challenges and breakthroughs

Site selection and land acquisition

One aspect, which caused unexpected delays to the project, was the issue of site selection and land acquisition. Due to the high-density nature of Dar es Salaam, it was challenging to find suitable and available land.

BORDA developed site selection criteria, which considered aspects relating to:

- Location (i.e. proximity to densely populated neighbourhoods for economy of scale; proximity to existing wastewater treatment facility; accessible by road; not located in a flood zone or difficult terrain)
- Size (i.e. sufficient area for construction of an FSTP; sufficient area for underground infiltration of treated wastewater, for irrigating trees), and
- Engagement of the local government officials in the process to select and obtain public land, and provide it for the implementation without any costs.

It took more than 1.5 years to obtain land instead of initially forecasted time of 6 months. This was after visiting 45 sites, evaluating 17 shortlisted sites, in order to select and obtain two sites, which were provided as in-kind contribution from the Municipalities: one in Mburahati ward, Ubungo Municipality (adjacent to the Barafu sub-ward office, 450m^2) and one in Miburani ward, Temeke Municipality (on the land of the Wailes/Likwati public school, 850m^2). These two sites then required construction approval from the Municipal Council, which was only possible after community acceptance of the project and the Municipality officially changed the land use. The success in finally obtaining land was due to the commitment of the LGAs and the partnerships with Barafu sub-ward, Wailes sub-ward and, the primary schools of Wailes/Likwati, who supported this project to be implemented within their jurisdictions.

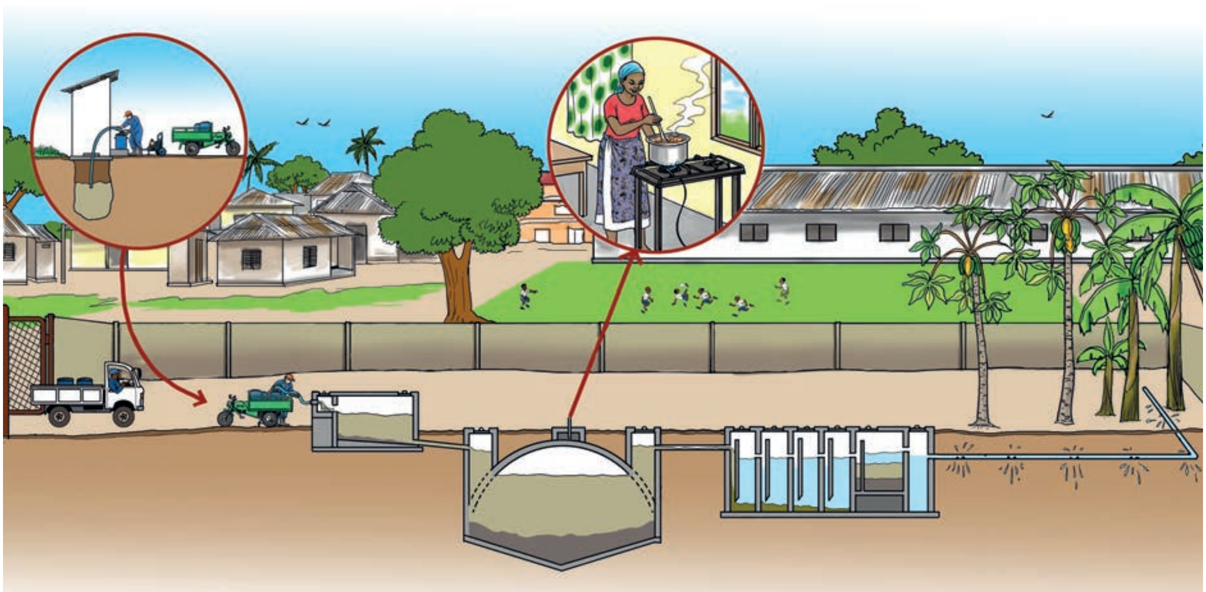


Figure 55 Setting of small-scale decentralised FSTP in Miburani-Temeke

Financial and institutional arrangements to operationalise the FSTPs

Several local business entrepreneurs were invited to workshops where the FSM concept and business opportunities were explained in detail. Although they were interested in the concept, they all faced similar challenges such as:

- Few private enterprises were willing or able to invest in the start-up equipment as there were no reliable data available to demonstrate the feasibility of the business concept, and the finance models were mainly based on assumptions.
- Financial institutions were either unwilling to provide loans, or interest rates were so high that the loans were prohibitive for prospective entrepreneurs.
- Very few service-providers had sufficient experience in FSM.
- Experience from solid waste shows challenges of collecting service fees from households with many unwilling to pay the fees.

Eventually BORDA publicly tendered and selected the most promising service providers

In the case of Mlalakuwa, BORDA provided financial and technical support to the local entrepreneur, in order for him to rent the necessary equipment. However, even with this support, he was unable to provide regular pit emptying services, mainly due to lack of WTP from the clients. This, in turn, meant that the community were reluctant to pay for services – although they cost only 50,000TZS per $3m^3$ – due to a perceived inconsistent commitment and irregular service provided by the operator. This challenge led to the new approach of centralised management of decentralised sites, as mentioned in more detail below.

Similarly, in the case of Mburahati, a local entrepreneur was contracted to provide E&T services. But due to the slow pay-back period to break- even (best case scenario estimated at 9 months, worst case scenario estimated at 21 months), small economy of scale at the beginning of operations and high interest rates on micro-finance loans for start-up equipment, the service provider quickly lost interest in serving the intended project areas (low-income households) and prioritised higher-paying clients such as hotels and businesses.

After these experiences at Mlalakuwa and Mburahati, the initial business concept involving private entrepreneurs proved to be unsuccessful. This revealed a number of important findings:

1. That profit-driven entrepreneurs have little incentive to serve the lower-income, inaccessible households, which require more time, more labour-intensive methods to empty their pits, and more trips to the FSTP using the motorised tricycle - compared to wealthier households with larger pits which are easy to access with vacuum truck.
2. In order to provide professional, reliable and inclusive FSM services particularly to those low-income households located in inaccessible areas, it became evident that the service would need to be cross-subsidised.

In continuation, the revised Water and Sanitation Act of 2019 states that all assets in connection to sanitation (including FSTPs) shall be managed by the public water authority (DAWASA): "16.-(1) *The ownership of waterworks, plant, equipment and other assets used by the Government, local government authorities or community organisations in connection with water and sanitation services together with any associated liabilities shall, without any compensation of the costs incurred, be transferred to the water authority upon its establishment."*

Figure 56 Construction of the Biogas Settler at Mburahati - Ubungo

With this new information that the FSTPs would eventually be managed by the public utility, the focus shifted from empowering local entrepreneurs, to instead empowering DAWASA – particularly as DAWASA also intends to scale up FSM at a city-wide level. In order to ensure a smooth transition, supervision and guided "handover".

The steering committee therefore agreed that BORDA should establish and closely monitor one 'centralised' team of service providers for a fixed period of one year to manage three decentralised treatment plants, and provide E&T services to residents in the project areas. The main objectives were to:

- Support the operators,
- Field-test different E&T equipment to develop innovative service provision models (e.g. 'eVAC', mud pump, trash pump, in different combinations with the motorised tricycle and small vacuum truck),
- Collect data on financial, environmental and social performance of the systems in order to optimise the service provision, and reduce the subsidies.

Within this period of closely monitoring the centralised management of decentralised systems, residents received reliable and affordable services and demand for services steadily increased, leading to the FSTPs operating at an increased daily capacity. Visibility of the service in the communities and demand for services continued to grow, meaning that the FSTPs and service provides can be handed over to DAWASA with the highest chance of sustained success, increased revenue, and ultimately minimal need for subsidised management.

Summarised output of the service provision:

From April 2019 to May 2020 (14 months) a total of 1,810m^3 of faecal sludge were collected in 623 trips and treated at the three FSTPs. This served the needs of approximately 15,500 people. Clients who received the service were interviewed through phone calls. 85% of the clients responded positive to quick availability and accessibility of the service to their sites. However, 37% of the clients who were interviewed were not comfortable with the amount they paid for the service.

Strengthened enabling environment

The lessons learnt throughout this project were regularly shared with high level stakeholders within the local and national sanitation sector. Recommendations relating to the enabling environment were provided upon request, specifically focusing on aspects of institutional arrangements, legal & regulatory framework, government support, socio-cultural acceptance, financial arrangements and skills & capacity. As a result, several major sector developments occurred during the implementation period of the project. Stakeholders who were involved in these processes were informed by the "DEWATS for DAR" project and appreciated the tangible experience it provided.

Although the process to implementing innovative FSM in Dar es Salaam was not straightforward, it ultimately proved to be a success story, as this project demonstrated that decentralised FSM can be successfully implemented in challenging urban settings. If the site selection criteria can be fulfilled, then FSTPs can be implemented. Likewise, this project demonstrates the potential of integrating underground FSTPs on small sites (e.g. directly bordering a Ward-Office, a central football pitch, a public school, households, small shops and restaurants) that fulfil the site selection criteria, allowing inclusive provision of FSM services in any other low-income urban settlement in Tanzania and other high density urban centres in Africa.

Learning

Learning: Stakeholder engagement
Stakeholder engagement is key for decentralised FSM. In all project phases and for all target groups exposure visits were a successful tool for creating awareness, and for capacity development. This helped to gain acceptance within the target communities, and was key for the training of operators and service providers. Additionally, it was a driver for developing awareness and acceptance of decentralised FSM as an appropriate solution for urban FSM challenges amongst decision makers and government agencies. Taking this into consideration, demonstration and training sites are essential for the transition from pilot scale to scaling up of an FSM innovation.

Additionally, stakeholder engagement is essential throughout the process and provides evidence-based advocacy for the revision of relevant legislations and standards (e.g. TBS, NEMC; LGAs), and for law enforcement once the service is available (e.g. Health Committee Members).

Site selection and land acquisition can only be achieved in close partnership with the LGAs as well as the local communities throughout the stages of the project, and particularly where public land is required for construction of FSTPs. This process can be time consuming and potentially a recurring challenge in most high density urban areas.

It is recommended that sufficient time (minimum 18 months) be allocated for site identification and land acquisition in the initial project planning phase for FSM interventions in high density urban areas. Where social and environmental impact assessments are required, an additional six months should be allocated.

The criteria for site selection for the construction of FSTP include the following:

1. Natural, Environmental and Physical Factors

- Land area (including space for disposal of effluent and sludge): should be minimum 450m^2 for a 10m^3 FSTP
- Accessibility: vehicle access to the site should be provided for construction, O&M
- Distance to the closest household: ideally the site should be located at least 50m from the nearest household
- Soil Characteristics & Conditions: Free soil (unconsolidated)
- Vulnerability to Natural Hazards (Flooding, Site Erosion)
- Ground water table: at least 2m deep

2. Legal, Institutional and Administrative Factors

- Proper Land Use: land-use zones allow for the construction of treatment facility in this location
- Ease of ownership: guarantee to be able to acquire land, either through purchase or in-kind contribution
- Settlement structure
- Future Expansion Plan: No risk to vehicular access due to future urbanisation or development

3. Socio-Economic and Cultural Factors

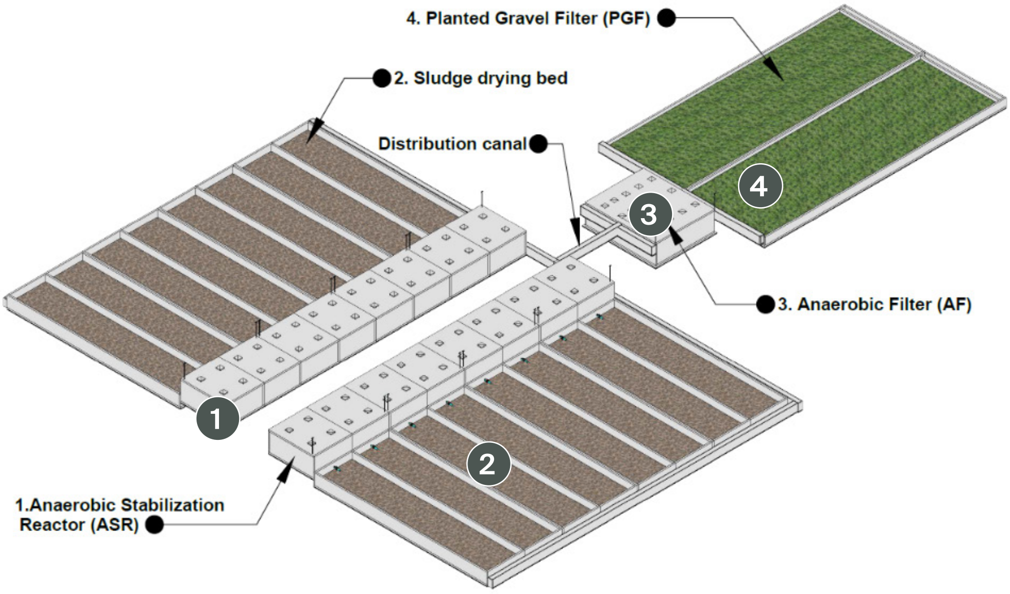
- Site Potential: close proximity to customers and demand (economy of scale)
- Support of the community: do they accept the intervention in their area
- Economic situation of the community: is the community willing and able to pay for sanitation services

Learning: Technology

FSTP: The DEWATS approach for FS treatment proves to be a good solution due to its low operational requirements and low-to-no nuisance emission. Nevertheless, the correct level of decentralisation needs to be determined for each context. The small-scale treatment plants can be very well integrated in urban areas, but if they are too small to accept vacuum trucks (smaller than 10m^3/day), a continuous inflow of FS and cost recovery are difficult to achieve. On the other hand, if they get too large, the reuse of the treated liquid fraction of the FS is challenging (depending on the availability of land for e.g. subsurface irrigation). It was observed that constructing subsurface irrigation schemes in public areas is challenging due to interference with other activities, which can even lead to damaging of the system.

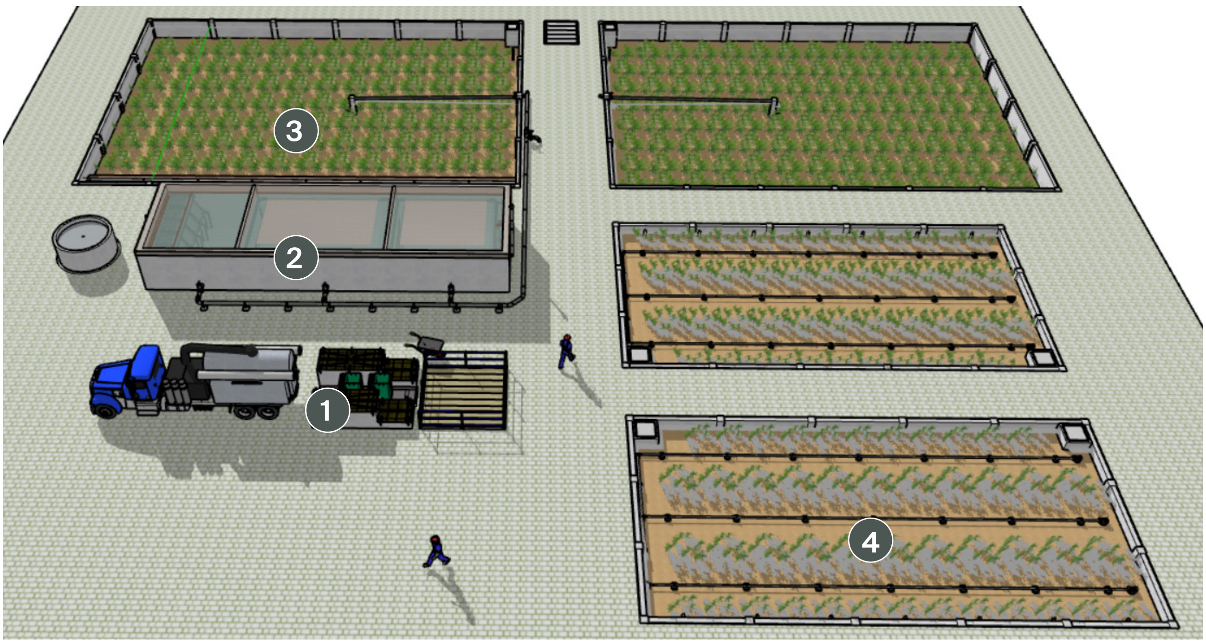
The combination of Biogas Settler, ABR/AF and unplanted drying beds is applicable for small-scale FSTPs. Based on international experience the treatment process for medium scale FSTPs can be designed as outlined in Figure 56 and Figure 57.

Treatment performance of the FSTP: The treatment performance of the systems is satisfying, taking into consideration their simplicity and robustness. The effluent can be safely used to irrigate crops, which do not get in direct contact with the irrigation water (e.g. bananas or papayas) or for sub-surface landscape irrigation.



Receiving station, Anaerobic Stabilization Reactor (1), Unplanted Drying Beds (2), AF (3), PGF (4) and Co-composting

Figure 57 FSTP for up to 50m^3/day



Receiving Station (1), Anaerobic Stabilization (2), optional with biogas, Planted Drying Beds (3), Vertical Flow Constructed Wetland (4)

Figure 58 FSTP for up to 200m^3/day

Faecal Sludge Systems	COD [mg/l]		TSS [mg/l]		E. coli [CFU/100ml]	
	Raw	Eff.	Raw	Eff.	Raw	Eff.
Concentration						
Average	1,086	226	918	153	$2.8*10^6$	$4.3*10^4$
75% of Samples <	2,320	321	1,261	204	$9.5*10^5$	$2.4*10^4$
Reduction rate						
Average	96%		94%		2.4 log-reduction	

Table 28 Treatment performance of FSTPs in Ubungo, Temeke and Kinondoni

E&T Technology	Investment cost (app. in USD)	Average Performance
Medium- / Large-scale		
Small Vacuum truck ($3.7m^3$ capacity)	25,000 (good condition, second hand)	▶ Trips per day: 2 - 3 ▶ Time per trip: 2h ▶ Distance per trip: 20km
Small-scale		
Motorised Tricycle (max. $1m^3$ capacity)	2,000	▶ Trips per day: 1 - 2 ▶ Time per trip: 1h30min ▶ Distance per trip: 4km **A trip started at the location the E&T equipment is waiting for customers and ends at the FSTP where the collected FS is discharged*
Mud / Water Pump	400	
Trash Pump	1,000	
'eVAC'	4,000	

Table 29 Summary of the E&T equipment – Investment Costs and Performance

E&T technology: Within this project a variety of E&T technologies were tested. A summary of the learnings (based on data collected during this project) is provided in the table above.

Learning: Cost recovery model

The project strived to develop sustainable cost recovery models that takes into consideration affordability by households in low-income urban settlements and recovery of operational costs. It was observed that the recruitment of an entrepreneur who operates a business based on collecting FS and operating the FSTP is challenging in the current context of Dar es Salaam. These experiences revealed that it takes time to build the FSM business, therefore service providers need to be supported or have other sources of generating income whilst the FSM business is developing.

Innovative approaches which make service provision more efficient are required for cost reduction and increased service coverage. Promising solutions are scheduled emptying, optimised citywide sanitation planning and an FSM phone-based application, which connects customers, FS collectors and the treatment plants.

It was observed that the **cost of providing the improved service was higher than the willingness to pay by the households**. The fees collected from the households could cover only 50% of the O&M costs. This is a hindering factor for the private sector to invest in the FSM services, but these lessons will now guide DAWASA to consider the necessary financing mechanisms as they plan to take over the FSTPs and the FSM service provision. It was concluded that the provision of FSM services which protect the environment and the public health require cross subsidies to sustainably finance the operational costs of emptying, transportation and treatment. This could be in the form of a sanitation levy on the water bills.

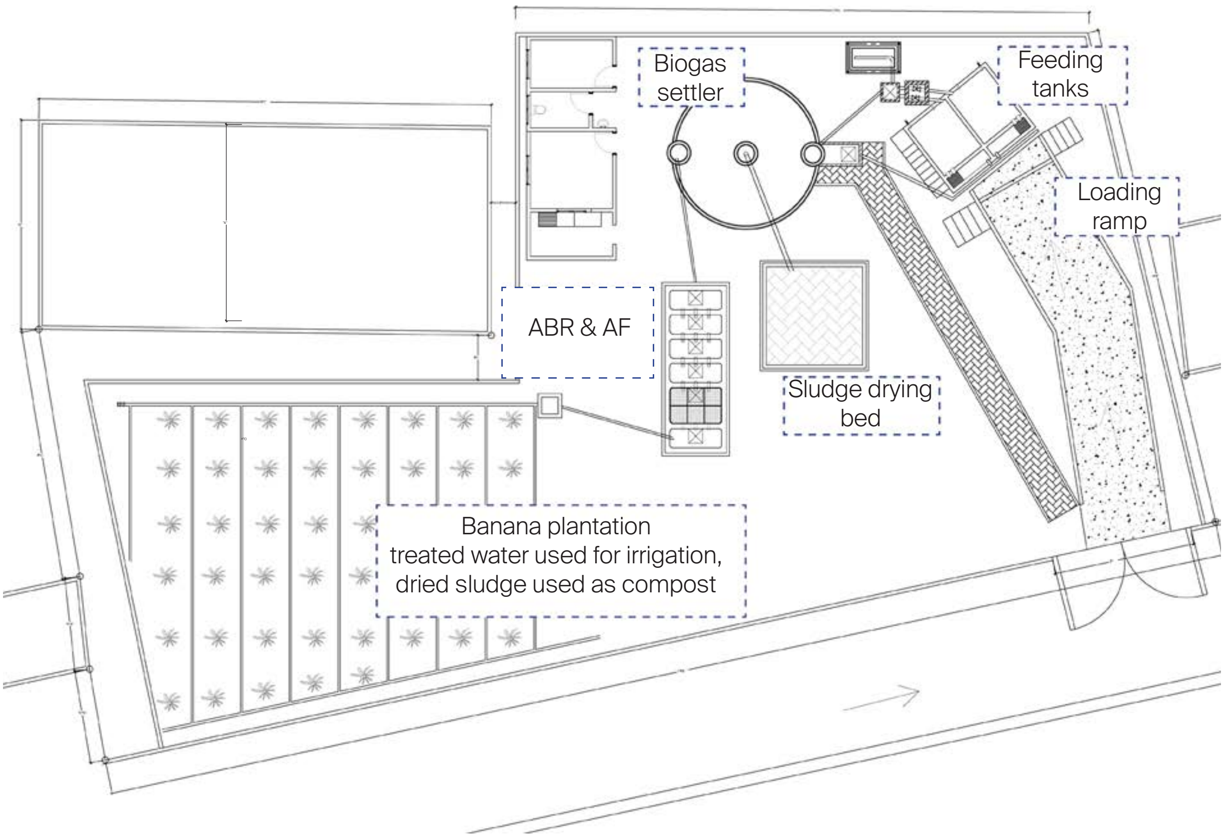


Figure 59 Layout of Miburani-Temeke FSTP

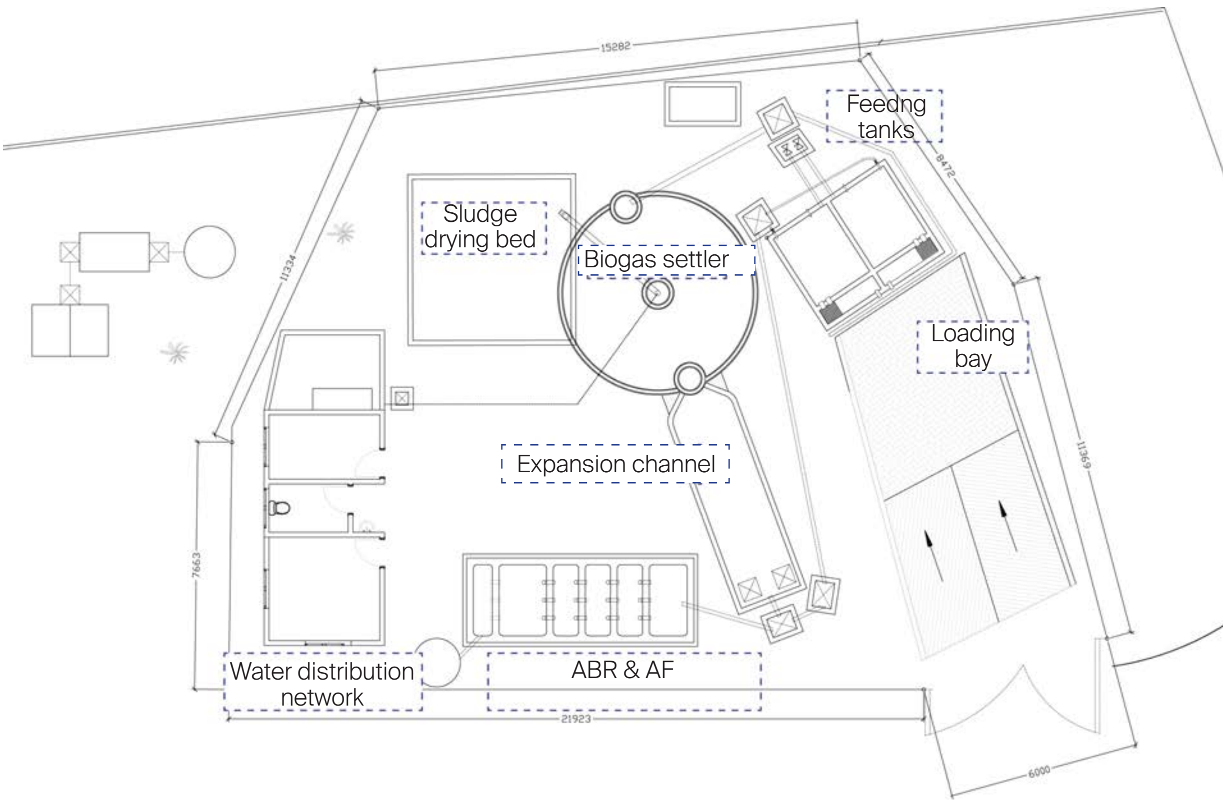


Figure 60 Layout of Mburahati-Ubungo FSTP

3.3 Enabling factors for OSS & FSM

The Three Cities OSS and FSM Knowledge Exchange Case Study provides detailed highlights of the capacity development initiative that was undertaken in three sub-Saharan African cities: Kampala (Uganda), Dar Es Salaam (Tanzania) and Lusaka (Zambia). The Knowledge Exchange initiative was aimed at enabling key stakeholders from the three cities' municipal/local authorities, commercial water and sanitation utilities, and regulators to make informed decisions in the field of OSS and FSM by learning from and exchanging on the approaches, opportunities and challenges of existing OSS and FSM frameworks in the other participating cities.

Enabling factors that support service delivery along the OSS and FSM service chain were identified as:

- **Private sector engagement:** Private sector engagement and involvement is key to sustainability of FSM services as the private sector can venture into areas where government and municipal resources could be limited. The success of FSM in Dar Es Salaam is due to private sector engagement and support. Therefore, business start-ups in FSM should be supported by both the government and cooperating partners.

- **Technology:** Appropriate technology options should be promoted to ease the process of E&T and treatment of sludge. Technological success is contextual to the environment; for example, the success of the gulper in Kampala cannot be translated to Lusaka where most pits are characterised by huge quantities of solid waste.

- **Institutional arrangements:** Institutional setups strengthening coordination of activities for all the stakeholders is very important in FSM service delivery. Utility and city collaboration at policy, technical and operational levels is cardinal for service success.

- **Capacity building:** The safety of OSS and FSM services for all stakeholders depends on the capacity in the sector. Therefore, service providers, legislators and enforcers need to be well informed by capacity building measures for service delivery.

- **Laws and enforcement:** The safety of OSS and FSM services lies in the success of enforcement at all stages of the service chain. Therefore, enforcers should ensure service providers' compliance with environmental, occupational health and safety laws.

- **Community engagement:** Community engagement is key to the implementation of FSM services that culturally are difficult to accept. The community can advise on the best approaches for service success.

This case study was extracted and adapted from:
Simwambi, A., Roig Senge, L., Kapembwa, A. (2020). Three - City OSS & FSM Knowledge Exchange - Lusaka, Kampala and Dar es Salaam (Case Study). GIZ, BORDA. Free PDF available at: https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/3826.

- **Research:** Research partnerships should be enhanced in cities to improve sludge treatment and handling. Social and scientific researchers can inform stakeholders about the success of FSM in many contexts. Therefore, collaboration between service providers and research institutions should be promoted in all the cities.

- **Product acceptance and market:** The acceptance of and market for FSM products incentivises service cost and provision. Knowledge exchange on FSM products and their uses should be encouraged, including research and market development. High service charges are in most cases due to low service demand, hence service providers making their profits on one-off customers.

Figure 61 Inspecting manholes at Miburani-Temeke FSTP

Figure 62 FSTP construction site, Miburani

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Text	Tim Fettback Joyce Musira Laura Bright-Davies Evelyn Herrera Lopera Modekai Sanga Oscar Mbekenga
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Figure 63 <Pit emptying service with gulper

BORDA Tanzania
Rose Garden Road
Plot 312, Mikocheni
PO BOX 105744
Dar es Salaam
Tanzania