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FAECAL SLUDGE MANAGEMENT (FSM) NEEDS ASSESSMENT INTERVENTION STRATEGY REPORT, IWRM-4-WASH AND WWX2 PROJECTS, ADDIS ABABA, ETHIOPIA

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1. Introduction

This report presents the findings and recommendations of the Faecal Sludge Management (FSM) Needs Assessment in Addis Ababa, Ethiopia. The Assessment was done from 1 November 2021 through 10 November 2021. For the program, see Annex 1 – Programme. For the Terms of Reference, see Annex 2 – Terms of Reference.

1.1. About IWRM-4-WASH and WWX

The projects "*Integrated Water Resources Management for Water Sanitation and Hygiene (IWRM-4-WASH)*" and *"WWX2"* promote a Market-based Approach and focus on improving water resource protection in Addis Ababa's water catchment by scaling up IWRM approaches with special focus on increased water and sanitation supply and strengthening market-based approaches towards sustained water and sanitation services provision for realization of Sustainable Development Goal (SDG) 6.

The IWRM-4-WASH and WWX2 projects are five-year projects to be implemented in the catchment areas of Legedadi, Akaki, Dire and Gerfesa, through funding by the Embassy of the Kingdom of the Netherlands (EKN) and the Ministry of Foreign Affairs (MoFA). They will be implemented by Vitens Evides International (VEI, Lead partner) in partnership with SNV Netherlands Development Organization (Implementing Partner) on the one hand, and Addis Ababa Water and Sewerage Agency (AAWSA, Beneficiary Partner) and Oromia Water Bureau (OWB, Beneficiary Partner) on the other. In addition, the project will work closely with associated water utilities of Akaki, Burayu, Gelan, Salulta and Sendafa.

The development objectives of the IWRM-4-WASH and WWX2 projects are to improve water resource protection in Addis Ababa's water catchment by up scaling and anchoring IWRM approaches with special focus on increased water and sanitation supply benefiting approximately 1.3 million people and strengthening market-based approaches to stimulate self-sufficiency and sustainability of water and sanitation services in line with the provisions of the Sustainable Development Goals (SDGs).

1.2. Background of the partnership in Addis-Ababa

In Ethiopia, utilities are organized at municipality level and the responsibility of the water supply service for towns and cities is given to utilities. So far, utilities are operating by themselves, and the Ministry of Water and Energy is establishing a utility regulatory body in the near future. The Federation of Ethiopian Water and Sanitation Utilities with close to 59 member utilities was established in 2018 to serve as reporting and communication channel between the utilities and the line Ministry, in addition to improving the capacity of member utilities.

The Addis Ababa Water and Sewerage Authority (AAWSA), the largest WSS utility in the country, is the sole entity mandated to provide potable water and sanitation services to residents of the city. It was established as an autonomous body by order No. 68/1971 issued in 1971. It has since been re-organized in 1995 and 2003. It is now entrusted to:

1. Supply safe and adequate water within the limits of Addis Ababa City;
2. Provide wastewater, sludge collection and disposal services;
3. Ensure that water resources are protected and conserved;

4. Determine the quantity of water to be supplied and wastewater to be disposed; and
5. Ensure that water quality conforms to standards.

Although there is no direct reporting channel between AAWSA and MoW&E, the high-level policies developed by the Ministry govern AAWSA's day to day operation.

The authority is responsible for serving about 4 million residents with water and sewerage services. The authority has connected about 700,000 customers with 3.5million people having access to water supply.

AAWSA operates two wastewater and sewerage treatment plants, one in Kality and another one in Kotebe. The Sewer systems are designed to align with the catchment areas in Kality and Katobe. Wastewater and sewage stabilization ponds have been established in Kality, Kotebe and Akaki.

AAWSA reports to a supervisory board chaired by the City Mayor, with membership from key stakeholders. Every quarter, there is a platform for the board members to review progress reports and endorse annual operational plans of the utility. The day-to-day operation of the utility lies under the General Manager (GM) of AAWSA who is supported by four deputy GMs that are responsible for:

1. The study, design and construction of water supply and sanitation infrastructures (Project Office);
2. The water supply and distribution;
3. The wastewater management (collection, treatment, safe disposal, and reuse), and
4. The resource management.

Nine branch offices report directly to the GM the day-to-day customer management and cascaded functions of the utility. The utility is autonomous from the city authority and from the line Ministry of Water for the management of the overall activities within the organization. AAWSA has in total 4,333 staff members. From this, 3,334 workers are permanent, and 999 workers are contracted. The sewerage department has a total of 441 workers.

The Addis Ababa City Government is one of the major stakeholders of AAWSA. The city government continues to finance close to 80% of the utility's capital investment requirements every year. The different sector bureaus in Addis Ababa such as the Road Authority, the Electricity and Ethiopian Telecom, the land management and administration bureau and the Oromia regional state, where majority of the water sources of the utility are found, are the major stakeholders of the utility. Customers of AAWSA (the city population) including many private sector entities such as industries, hotels, the airport et cetera who demand the continuous service of the utility are also considered as key stakeholders of the utility.

1.3. Description of AAWSA service area and recent performance

Addis Ababa is located in the central plateau of Ethiopia. The living standard of the population contains both modern areas (well-designed and constructed houses) and informal areas. The city has a total land area of about 520km^2 and is sub-divided into ten sub-city (administrative regions) areas. From the census data of 2007 the population of the city was 2,739,551 with a growth rate of 2.10%. Addis Ababa is an important political and diplomatic hub of Africa where close to 25% of the country's urban population resides. The fast urbanization, population growth, and the presence of several international organizations in the city pose a serious development challenge for service providers like AAWSA.

The city uses water from both surface- (37%) and groundwater sources (63%). Currently, it is difficult to differentiate which part of the city gets water from which source, as the system is mixed. Generally, the eastern and northern parts of the city use more surface water sources (from the Gefersa dam), the western and middle part of the city receive both surface and groundwater (Legedadi dam and Legedadi groundwater well-field), and the southern part gets water mainly from groundwater (Akaki well-field).

Due to rapid urbanization, the lifestyle of city dwellers is changing, and many new condominiums are under development. As a demonstration for its fast urbanization, a government-led housing development project is planned by the Addis Ababa city government with a target of some 50,000 houses every year. Since these condominiums include modern water and sanitary facilities, they consume more water, increasing demand for city water supply. In addition, the city is undertaking many expansion and construction projects (e.g., industrial, offices and international hotels). Because of the rapid urbanization, there is a considerable migration from the rural part of the country, further increasing the water consumption and creating water supply and sanitation services challenges.

According to the AAWSA Growth and Transformation Plan (GTP II) Addis Ababa requires close to 1million cubic meter of water every day to meet the current and estimated future (2020) water demand of the city (including commercial demand). So far, following the intensive effort from AAWSA, the daily production capacity of AAWSA is increased from 350,000m^3 some 6 year back to 700,000m^3/day. However, the high volume of Non-Revenue Water (NRW), which is estimated at 40% out of which close to 17-20% is considered as technical losses, limit AAWSA to fully supply the produced water to the wider customers.

2. Policy and Institutional Guidelines on Faecal Sludge Management

Ethiopia does not have a stand-alone sanitation policy, but sanitation development strategies are captured in the health, environment, water, and urban development sector policies. The institutional fragmentation of urban sanitation has compromised a shared understanding of the scope of urban sanitation, and there is no common agreed problem statement, no consensus on priorities, and unclear mandates in addressing waste management demands.

In 2017 the key ministries endorsed a cross-sector Integrated Urban Sanitation and Hygiene Strategy (IUSHS), with the aim pulling together the relevant strands of different sector policy documents, clarify the big picture, enhance greater organizational synergy, and refine the mandates of the different ministries. However, with several institutions involved in urban sanitation service delivery from federal to town level, this process will continue as the respective institutions come to terms with evolving urban sanitation challenges.

The roles of multiple institutions are still evolving at all levels. At federal level, the MoUDH, MoH, MoWE, Addis Ababa Environmental Authority and Ministry of Environment, Forestry and Climate Change are the key institutions involved in urban sanitation policy setting, strategy formulation, and developing national guidelines. At regional level, several bureaus are involved in capacity building, funding, and monitoring of urban sanitation activities, resembling the institutional arrangements at federal level, typically with an office responsible for sanitation, beautification, and greenery in the regional Urban Development Bureau. Some Regional Water Bureaus are now interested in sewerage systems, especially for the MoW&E's proposed wastewater interventions in six cities earmarked for sewerage. Liquid waste management is also supported by the Regional Health Bureau, focusing mainly on promoting hygiene and sanitation at household level. There are overlaps in the regulatory roles of the agencies responsible for Health, Culture and Tourism, Water and for Environment and monitoring and enforcement capacity is generally not strong. Provision of urban sanitation services is undertaken at town level. The key institution at the town level is the municipality which is responsible for the provision of waste management services. In some towns water utilities are in charge of liquid waste management but in the overwhelming majority (over 95 percent) of towns, the municipality remains the key institution.

Addis Ababa Water Supply and Sewerage Authority (AAWSSA) is responsible for water supply and management of wastewater and sanitation waste disposal. The policy and regulation of water supply and wastewater disposal falls under several government ministries and agencies including;

- Ministry of Water and Energy (MoW&E);
- Ministry of Health (MoH);
- Ministry of Agriculture;
- Ministry of Environment and Forestry;
- Environmental Protection Authority;
- Ministry of Urban Development and Construction;

- Urban Agriculture Department under the Addis Ababa City Administration.

The lack of a single institutional home for urban sanitation and particularly faecal sludge management presents gaps in the duties, plans, policies, and strategies for the management of sanitation waste. The agencies whose policies directly relate to the regulation and management of sanitation waste were found to have overlapping authority in the management of wastewater and sanitation. As such, there is no clear implementation approach in the management of faecal sludge in the Addis Ababa or other regions. The following is a list of policies, regulatory Strategies and institutional frameworks that relate to the management of wastewater and Sanitation waste in Ethiopia. The policies and regulations must be considered when undertaking a project or initiative that touches on sanitation and wastewater management.

- **The Constitution of the Federal Democratic Republic of Ethiopia:** The Federal Democratic Republic of Ethiopia (FDRE) Constitution is the basis for all development-related policies, and legal provisions and related outcomes within the country. Article 44/1 of the Constitution gives all persons the right to live in a clean and healthy environment, while Article 92/1 of the Constitution states that the government has the duty to ensure this right. Article 92/2 of the Constitution requires that the design and implementation of development programmes and projects should not damage or destroy the environment (FDRE, 1994);
- **The National Health Policy (1993):** in Article 3: The Policy outlines the need for strategies linked to the democratisation and decentralisation of the health system, and inter-sectoral collaboration. It specifies the need for 'accelerating the provision of safe and adequate water for urban and rural populations', 'developing safe disposal of human, household, agricultural and industrial wastes and encouragement of recycling', and 'developing measures to improve the quality of housing and work premises for health' (Transitional Government of Ethiopia, 1993). The Health Policy has led to several health-related programmes and strategies;
- **The National Hygiene & Sanitation Strategy (2005):** The strategy was developed to complement the existing health policy (developed by the MoH) and the national water sector strategy (developed by the Ministry of Water Resources) in placing greater emphasis on 'on-site' hygiene and sanitation. The primary focus is on blocking faeces from entering the living environment through the safe management of faeces, hand washing at critical times and the safe water chain from source to mouth. It places responsibility for improving 'on-site' household hygiene and sanitation firmly in the hands of the household with the direct support of the health extension worker and other resources at community level. The strategy is harmonised with the Health Sector Development Programme which places a strong focus on high impact, broad reach, public health interventions;
- **National Protocol for Hygiene and "On-Site" Sanitation (June 2006):** This was created to align with the national strategy for hygiene and sanitation improvement. Its focus is to promote universal access (100%) to hygienic and sanitized households) in the peri-urban area and in the primarily rural environments;
- **National Manual on Latrine Technology Options:** This provides a general guidance on the recommended types of latrine technologies and other factors to consider when selecting a latrine technology. This

includes the improved pit latrine (Arborloo-single pit and Fossa Alterna-double pit) designs, water carriage latrine systems;

- **WASH Memorandum of Understanding:** signed among Ministry of Health, Ministry of Education, Ministry of Water, Irrigation & Energy; and Ministry of Finance & Economic Development. The memorandum is focused on integrated implementation of water supply, sanitation, and hygiene program in Ethiopia;
- **Environmental Policy of Ethiopia (1997):** is the integrated implementation of water supply, sanitation and hygiene program in Ethiopia primary policy for the environment and natural resource management in Ethiopia. Section 6.3.2. – focuses on policy recommendations on infrastructure for water, sanitation and solid waste management;
- **National Guideline for Environmental Impact Assessment (July 2000):** The document provides a background to environmental impact assessment and environmental management in Ethiopia. In essence the document aims at being a reference material to ensure effective environmental assessment and management practice in Ethiopia for all parties who engage in the process. In addition, it captures rural and urban water supply and sanitation and waste disposal elements

National Guideline for Urban Water Utilities Tariff Setting: the purpose of these guidelines is regulate tariffs payable by urban dwellers for water provision and related services by factoring necessary costs for sustainable service provision of the service, protecting consumers from being unfairly charged and ensuring that a certain minimum quantity of water is accessible and affordable to all including the very low income category.

National Integrated Urban Sanitation and Hygiene Strategy (2015): This is a strategic document for the delivery of the Urban Sanitation and Hygiene program in all Ethiopian cities and towns classified as per the guidelines prepared by the MoUDH. The key areas covered by the Strategy include:

1. Liquid waste service delivery: including safe disposal of human excreta, liquid waste generated by human activities (domestic, industrial, and commercial waste), institutional waste and safe management of drainage
2. Solid waste service delivery: including solid waste generated by human activities (domestic, industrial, commercial, and institutional waste) and safe management of drainage
3. Promotional and behaviour change: including correct hygiene practices, use and management of latrines, uptake of and payment for services, eradication of open defecation, MHM, solid waste management (reduce, reuse, recycle) as well as other interventions.

Proclamation 300/2002, Environmental Pollution Control: This proclamation covers 22 articles that provide guidelines on Pollution control, Environmental standards, Environmental inspectors, Offences and penalties and other miscellaneous provisions.

Solid Waste Management Proclamation No. 513/2013: the objective of this proclamation is to strengthen the capacity at all levels in ensuing order to prevent all possible negative impacts in the process of creating economically and socially beneficial assets from solid wastes.

2.1. Policy Challenges

The current urban sanitation and waste management situation (USWM) is poor and fraught with multiple operational challenges. In addition, some policies are old and need urgent updating. There are no clear policies, regulation, strategies, or guidelines promoting USWM public-private partnership (PPP) in waste collection, transportation, reuse, and recycling. Waste management services in urban areas are poorly coordinated and difficult to systematically regulate.

2.2. Challenges in the implementation of urban sanitation and waste management policies

Poor implementation of existing national and regional policies and guidelines, low levels of public awareness, and lack of consistent separation at the source—particularly from households—results in 70- 75% of organic decomposable waste that could be used for compost or to produce methane to generate energy being taken to landfills/dumpsites. A study conducted by USAID documents the challenges faced by sanitation and waste management operators and they include:

1. Insufficient budget and absence of a cost-recovery mechanism;
2. Lack of proper truck maintenance;
3. Absence of incentive systems;
4. Low private-sector involvement
5. Lack of promotion and education on waste reduction, recycling, recovery, composting, and energy generation;
6. Poor organizational structure and function of waste management services for human resources and logistics;
7. Weak collaboration between stakeholders for sanitation and waste-management activities;
8. Lack of training and financial support for micro-enterprises;
9. Lack of space to construct latrines in overcrowded slum areas;
10. Failure to syntheses and disseminate best practices for waste management services.

2.3. Recommendations

1. Harmonize and implement national and regional policies, strategies, and guidelines on sanitation and waste management services to avoid duplication of efforts, overlap, and unclear roles among various stakeholders;
2. Strengthen the links and support between national, regional, and local USWM sectors;
3. Implement the Integrated Urban Sanitation and Hygiene Strategy;
4. Develop strategy to promote inter-sectoral collaboration;
5. Strengthen partnerships between stakeholders engaged in sanitation and waste management.

3. Faecal Sludge Management Situation Analysis

In this chapter we review the current conditions:

- We describe the field conditions, based on literature and our own observations in sections 3.1-3.4;
- We analyse the challenges faced, based on the review of the field conditions in section 3.5.

Use of icons. Throughout this report we apply icons to illustrate clearly what is meant with the different systems, as most readers are more familiar with piped water supply systems. As the icons are meant to support, we only numbered the illustrations that are referred to in the text. The icon to the left illustrates the basics of a pit latrine.

3.1. Onsite systems

Basis. The review of field conditions is based on physical inspection in the field, interviews held on two occasions (2 November 2021 and 4-5 November 2021) and literature reviews.

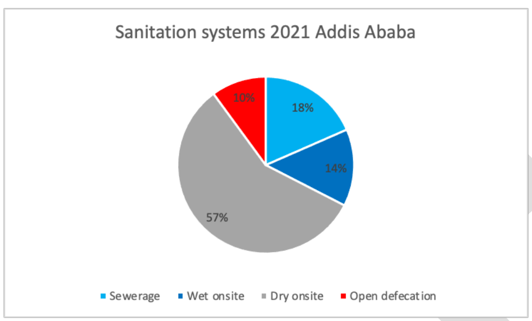


Figure 1 Sanitation systems in Addis in 2021 (Source: Tamene Hailu Debela et al, 2018)

Findings. The types of sanitation encountered in the field and their status are as follows:

Around 60% of the households in the urban areas (see Figure 1, usually those without piped water) use direct drop (dry) **pit latrines,** detached from their houses. Pit latrines in Addis Ababa are typically unlined and 1.5–4m' deep. They are normally dry, but water may be used in the case of some pour-flush toilets. The roof and the wall are usually made of corrugated iron sheet, and less commonly of wood with mud or concrete. The slab is usually made of mud-plastered wooden materials and sometimes unreinforced concrete (which provides a washable floor). As most city residents are poor, many shared communal toilets have been constructed by government and nongovernmental organizations to higher standards than household level pit latrines.

There are serious risks related to poor sanitation and improper treatment of faecal waste in Addis Ababa. Faecal contamination of groundwater and surface waters is widespread, with shallow wells (compared to deeper boreholes) and downstream sites presenting the highest risks (*Source: Tamene Hailu Debela et al: Faecal contamination of soil and water in sub-Saharan Africa cities: The case of Addis Ababa, Ethiopia, Ecohydrology & Hydrobiology 18, 2018)*. Figure 2 illustrates the pollution by pit latrines.

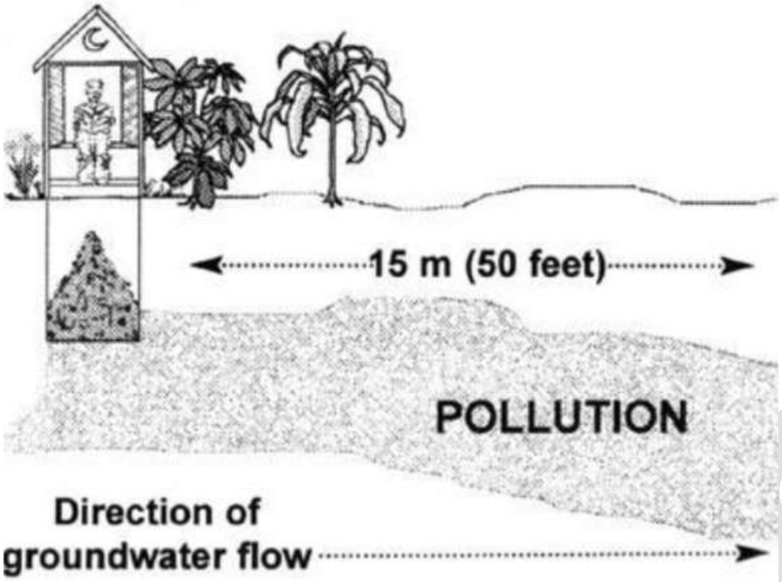
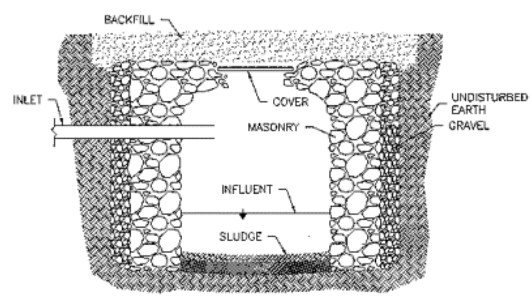


Figure 2 Pollution dry pit latrines (source: Franceys, R. et al., 1992, A guide to the development of onsite sanitation, page 40, WHO, Geneva)

Once full, the latrine is abandoned and a new one built. Alternatively, a lot of water is added, and the toilet is emptied by means of a vacuum truck.

Issues are:

- Limited user comfort;
- Potential pollution of shallow wells as the distance to the well (of the neighbours) is usually short. However, as the hydraulic load in the system is small (no showering in the latrine, dry materials used for anal cleansing) this issue is most likely limited;
- Difficult to access during the night and rainy season;
- Potential safety issues for woman and girls at night;
- The squat hole is open, and flies and mosquitoes can freely access the pit contents, spreading diseases;
- Prone to collapse during rainy season or when trying to empty.



Households with piped water and enough space convert their latrine into a **single leaching pit** often erroneously named 'septic tank' (around 14% of the population, see Figure 1). The user interface often consists of a (pour-) flush toilet with a goose neck (that prevents foul smells). The leaching pit is a concrete block lined, single pit. Whereas this toilet provides a high level of user convenience to the household (can be in-house, no smell), a major issue is the groundwater pollution due to the hydraulic load which is much higher than in case of the dry latrine. This is

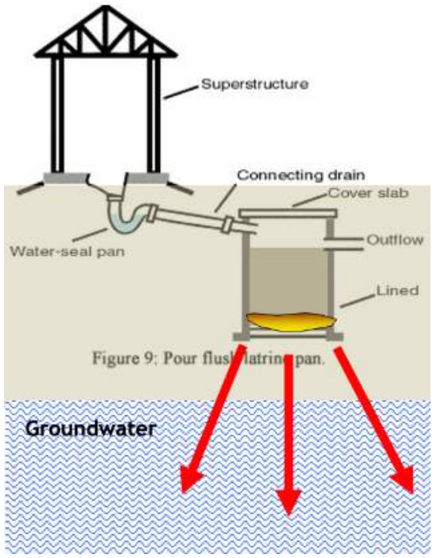
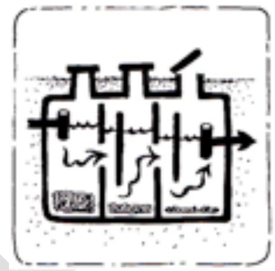


Figure 3 Groundwater pollution by wet onsite systems

an issue where shallow wells are used for drinking water. When full a lot of water is added, and the toilet is emptied by means of a vacuum truck.

3.2. Decentralized systems



Addis has many high-rise buildings (Figure 4) where the wastewater of a number of houses is collected in a so-called condominium sewerage system connected to a decentralized treatment systems such as 18 Anaerobic Baffle Reactors (ABR, see Figure 5) and 12 Membrane Bio Reactors (MBR, see Figure 6).

Figure 4 High-rise building connected to decentralized treatment systems (Source: WWX field visit 2 November 2021)

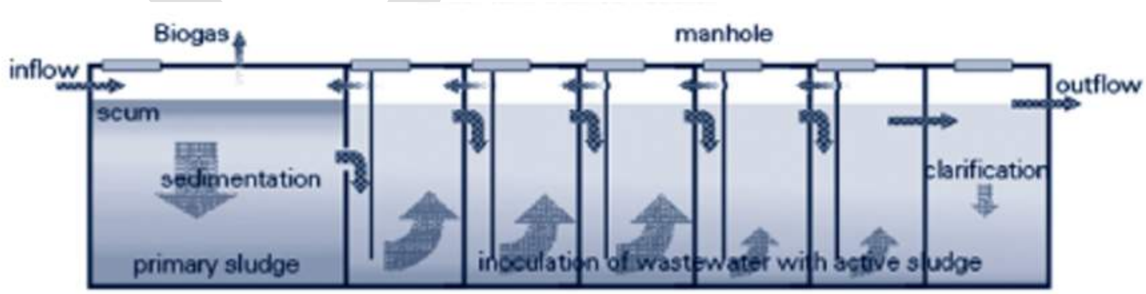


Figure 5 Anaerobic Baffle Reactor (Source: BORDA)

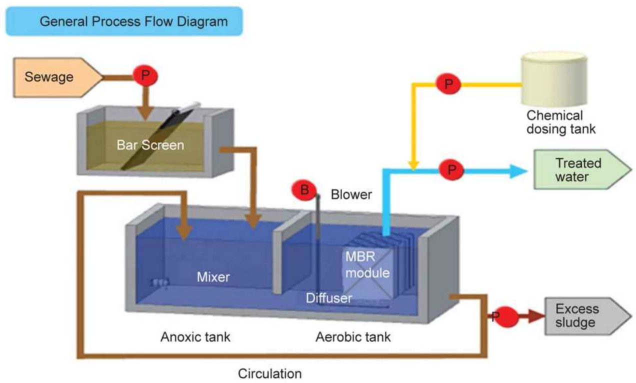


Figure 6 Membrane Bio Reactor (source: www. cmmembrane.com, accessed 8 November 2021)

Concrete ABRs are usually expensive to construct. However, as there are no pumps and moving parts, the Operation and Maintenance (O&M) is minimum and restricted to the periodic removal of sludge. An ABR also produces biogas that can be used for heating, cooking or electricity production. After the construction of the trunk sewers, the decentralized systems are to be abandoned, see Figure 7 and Figure 8. Hence, it could be envisaged to use cheaper material such as Glass Fibre Reinforce Plastic (GFRP) and reuse the ABR in future projects, see Figure 9 and Figure 10.

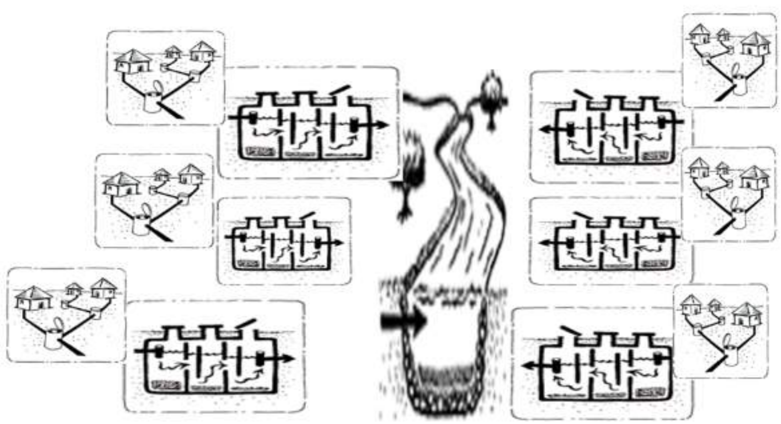


Figure 7 Decentralized treatment into rivers

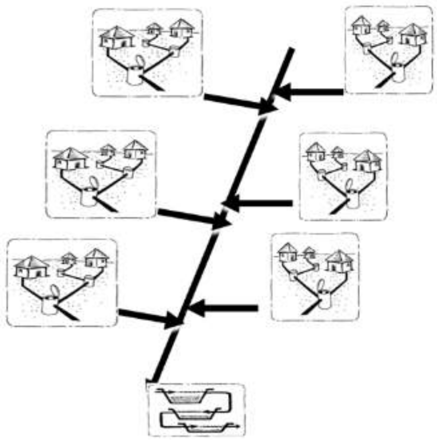


Figure 8 Condominium sewers connected to trunk sewer

Figure 9 Prefab GRP ABR (Source: BORDA, 2012)

Figure 10 Transfer prefab ABR (Source: BORDA, 2012)

The MBR connected to the condominium sewerage of AAWSA that we visited, was in excellent condition. It was operated and maintained in a very professional way. However, MBRs are very expensive to construct, operate and maintain. In the future AAWSA intends to outsource the O&M to private parties (info field visit 2

November 2021). The effluent of the MBR we visited was of excellent quality, hence the product could easily be used for irrigation. See Figure 11.

Figure 11 Effluent MBR (Source, field visit WWX 2 November 2021)

3.3. Emptying of onsite systems

Vacuum trucks. AAWSA has fleet of more than 100 6m^3 Vacuum Trucks that empty onsite systems, see Figure 15. The private sector in Addis Ababa also has around 100 trucks and AAWSA has ordered another 100 trucks. Usually, the contents of the onsite system is too thick to pump and the household wanting to have the system emptied, is instructed to add a lot of water (info AAWSA on 1 November 2021). Hence, the trucks transport a lot of water that was originally not present in the onsite system, adding to transport efforts.

Bajaj vehicles. The Emmanual Development Organization reports to have around 50 2m^3 Bajaj vehicles that empty onsite systems, see Figure 12. The vehicles are used to feed biogas systems.

Figure 12 Bajaj septage vehicles (Source: Emmanuel Development Organization, visited 4 November 2021)

Figure 13 MDU developed in Ethiopia (Source: WASTE, 2018)

MDU. As part of the S(P)EEDKITS and the Emergency Sanitation project, WASTE has introduced a Mechanical Desludging Unit (MDU), manufactured by ROM in the Netherlands. The device is successfully introduced in Blantyre (Malawi) and Nakuru (Kenya). As part of the VIA Water program, WASTE has started production in Ethiopia in 2017, reducing the purchase price from almost €20k to less than €10k. The device is successfully tested in Ethiopia but has not been introduced on a large scale. The MDU has a high-pressure clean water pump with special nozzles that fluidizes the sludge, thereby reducing the need for adding clean water to 10-15%. After fishing out the solid waste, the sludge is transferred to the treatment and valorisation plant see You-tube video: https://youtu.be/KqrNTUZZY7Q .

Figure 14 MDU developed in Ethiopia (Source: WASTE, 2018)

3.4. Treatment of septage and faecal sludge

At the moment, AAWSA does not have a dedicated Faecal Sludge Treatment Plant. Both the septage from septic tanks and the diluted faecal sludge from pits is directly dumped into the ponds at the Bole WWTP in Kotebe, see Figure 15. Before dumping into the pond, the sludge is screened in metal container type screens. The screens remove course plastic waste such as diapers. AAWSA indicates that the capacity of the Bole WWTP is insufficient. Ideally the ponds are left for 3 months to settle and dry before bulldozers remove the sludge from the dry ponds.

Figure 15 Emptying of septage from 6m3 AAWSA vacuum truck in Kotebe pond after being sieved in a metal container type screen (Source: field visit WWX, 1 November 2021)

The Kality WWTP, see Figure 16, has stainless steel receiving bays.

Figure 16 Reception area septage at Kality WWTP (Source: field visit WWX 1 November 2021)

The dried sludge removed by bulldozers is informally removed by farmers at no cost. The dried sludge is full of plastics which makes reuse a challenge, see Figure 17.

Figure 17 Dried sludge full of plastics at WWTP Bole (source: field visit WWX, 1 November 2021)

Testing of the agricultural value of dried sludge. The agricultural value of the dried sludge of the Kality WWTP is tested in the fields next to the sludge drying beds. See Figure 18.

Figure 18 Sludge drying beds at Kality WWTP with testing plots of dried sludge at the righthand side (Source, field visit WWX 1 November 2021)

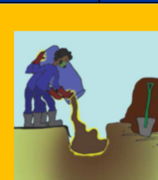
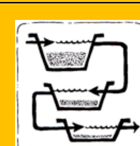
3.5. Summary findings sanitation

Figure 20 provides an overview of the systems found in Addis Ababa using the same icons as the illustrations used in the text above, considering sanitation as a chain of connection activities. Figure 19 shows:

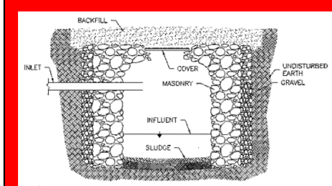
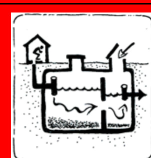
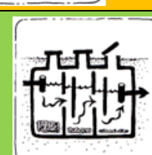
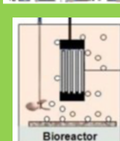
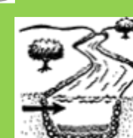
- The user interface (what most people refer to as 'the toilet');
- The containment, where urine, faeces, cleansing materials such as toilet paper, water used for flushing, etc. is being contained;
- Emptying and transport of the contents of the containment, once full;
- Treatment of faecal sludge (in case of a pit latrine and ABR) or septage (in case of a septic tank);
- Reuse of treated sludge (biosolids, compost) and treated effluent in agriculture and use of biogas (for cooking or electricity production).

Figure 19 Sanitation chain

Through a 'traffic light system' we have assessed the quality of the systems: good (green), fair (amber) and inadequate (red). The majority of the systems are dry pit latrines that provide limited user comfort and likely have an adverse effect on the quality of the groundwater. Many people with piped water supply use leaching pits / cesspools[1] that provide good user comfort but that are likely to pollute the groundwater significantly. There are 35 decentralized treatment systems. The one we visited performed adequately. Wet onsite systems are being emptied by over 200 vacuum trucks. The sludge is dumped into the 2 existing WWTPs. There are no dedicated faecal sludge treatment plants and there is no intentional reuse of treated septage, faecal sludge or wastewater.

User interface	Emptying conditions	Collection Storage / Local Treatment	Transport/ Conveyance	Treatment Reuse/ Disposal
Dry 	No or informal desludging services	(Ventilated Improved) Pit latrine  		
	Dilution with water and emptying by Vacuum trucks	Disposal into Waste Stabilization Ponds		

[1] A leaching pit / cesspool is an underground hole or container that is used for collecting and storing human waste and dirty water. Unlike a septic tank it is not watertight, and its contents severely pollutes the subsoil as the walls and bottom are not lined.

User interface	Emptying conditions	Collection Storage / Local Treatment	Transport/ Conveyance	Treatment Reuse/ Disposal
				
Wet 	Vacuum Tankers 	Cesspool / Leaching pit ('septic tank') 		
		Septic Tank & Soak away  		
		Disposal into Waste Stabilization Ponds  		
	None	Decentralized systems connected to an Anaerobic Baffle Reactor or a Membrane Bio Reactor    		
		Conventional Sewerage and Waste Stabilization Ponds or UASB 		

User interface	Emptying conditions	Collection Storage / Local Treatment	Transport/ Conveyance	Treatment Reuse/ Disposal
				

Figure 20 Assessment sanitation systems in Addis Ababa (Source: WWX, November 2021)

In short, the following challenges are found in Addis Ababa:

- Dry pit latrines provide limited user comfort and are likely to pollute the groundwater;
- Septic tanks are inadequately designed (cesspools), inadequately constructed (wrong design, leaking, no separate infiltration / soakaway pit), inadequately operated and maintained (full of sludge) and are an environmental threat: groundwater and surface water pollution, foul smells, mosquito breeding and a source of disease transmitting vectors like rodents and rats;
- Faecal sludge / septage is being discharged by vacuum trucks into the WSPs. No information of influent and effluent quality of the WSPs;
- The conventional sewerage system is in good order. The effluent is reported to fulfil environmental standards and is not reused intentionally. Biogas from the UASB is flared;
- Dried septage and faecal sludge is not reused intentionally.

4. Operational Mechanism for Faecal Sludge Emptying, Collection and Transportation

4.1. Population and water supply

Addis Ababa is a city with around 5 million people. It is expected to grow to 14 million people between 2021 and 2050. Around 60% of the population is connected to the piped water supply: 600,000 connections. The demand for drinking water is expected to grow from 200,000 m^3/day to more than 1 million m^3/day. See Figure 21.

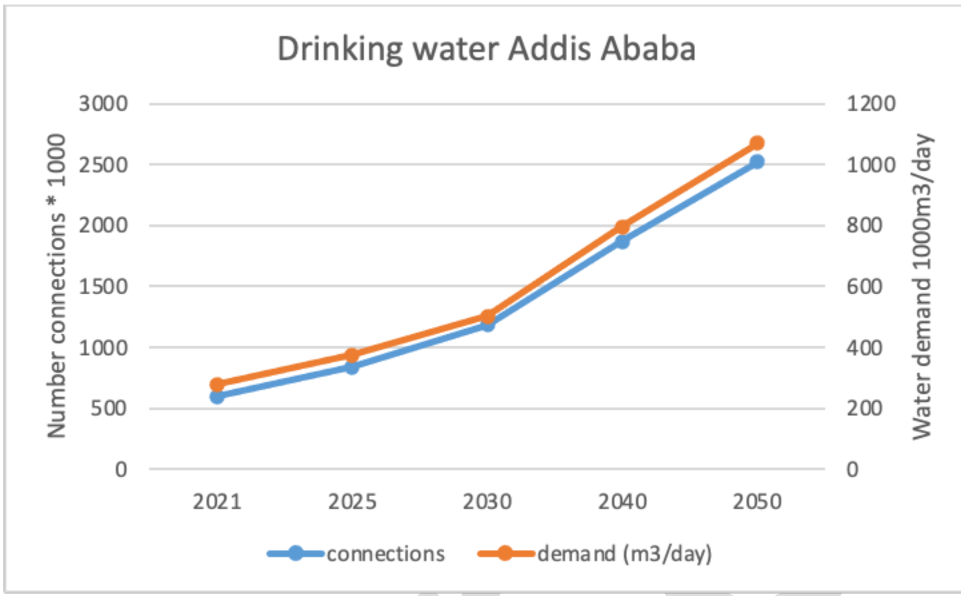


Figure 21 Projections drinking water Addis Ababa

Table 1 Projections drinking water Addis Ababa (Source: WWX, 2021)

Description	units	2021	2025	2030	2040	2050
Population (rounded)	capita	5,000,000	6,000,000	7,400,000	10,400,000	14,000,000
Population growth				4.28%	3.5%	3.0%
Persons per connection	capita/hh	5	5	5	5	5
Households (rounded)	hh	1,000,000	1,200,000	1,480,000	2,080,000	2,800,000
Water supply						
Coverage water supply connections	% pop	60%	70%	80%	90%	90%
Number connections (rounded)	hh	600,000	840,000	1,184,000	1,872,000	2,520,000
Drinking water consumption incl NRW	lcd	93	89	85	85	85
Drinking water production	m3/d	279,310	374,017	503,200	795,600	1,071,000

4.2. Definitions

FSM deals with the sanitation chain from containment in onsite sanitation systems to reuse. To design the emptying, transport, treatment, and reuse business models, it is important to realise that there is a pronounced difference between septage from septic tanks and the faecal sludge from pit latrines. In this report we use the historical term '**septage**' to define the contents removed from septic tanks and we use '**faecal sludge from pits**' to define sludge from other OSS systems: pit latrines, leaching pits, etc.

Septage is the combination of scum, faecal sludge, and liquid that accumulates in septic tanks; f**aecal sludge from pits** is the sludge that accumulates in pits. Both are a mixture of solids and liquids, containing mostly excreta and water, in combination with sand, grit, metals, trash and/or various chemical compounds.

Septage and faecal sludge from pits have not been transported through a sewer. It can be raw or partially digested, a slurry or semisolid and results from the collection and storage/treatment of excreta or black water, with or without grey water and with or without water used for fluidization.

4.3. Quantities

Quantities of faecal sludge produced within pits are expressed in terms of *sludge accumulation rates per person per year*. Many factors influence this accumulation rate e.g., diet and climate: but the most important factors are whether decomposition takes place above or below the water table and the type of anal cleaning material used. Decomposition under water (anaerobic digestion) is slower but results in a much greater reduction in volume than decomposition in air (aerobic digestion). Anal cleaning materials vary widely from those requiring little or no storage space, such as water, to those having a greater volume than the excreta, such as corn cobs, cement bags or stones. In Addis Ababa, volumes to be managed also include extra water which is used by some emptiers to facilitate pit emptying.

In absence of on the ground studies, our estimates on the quantities of faecal sludge produced are based on internationally rules of thumb presented in Table 2 which quote 60 litres per capita per year (dry pits, degradable anal cleaning materials).

Table 2 Maximum sludge accumulation rates (Franceys R., 1992)

DESCRIPTION	SLUDGE ACCUMULATION RATE
Wastes retained in water where degradable anal cleaning materials are used	40
Wastes retained in water where non-degradable anal cleaning materials are used	60
Wastes retained in dry conditions where degradable anal cleaning materials are used	60
Wastes retained in dry conditions where non-degradable anal cleansing materials are used	90

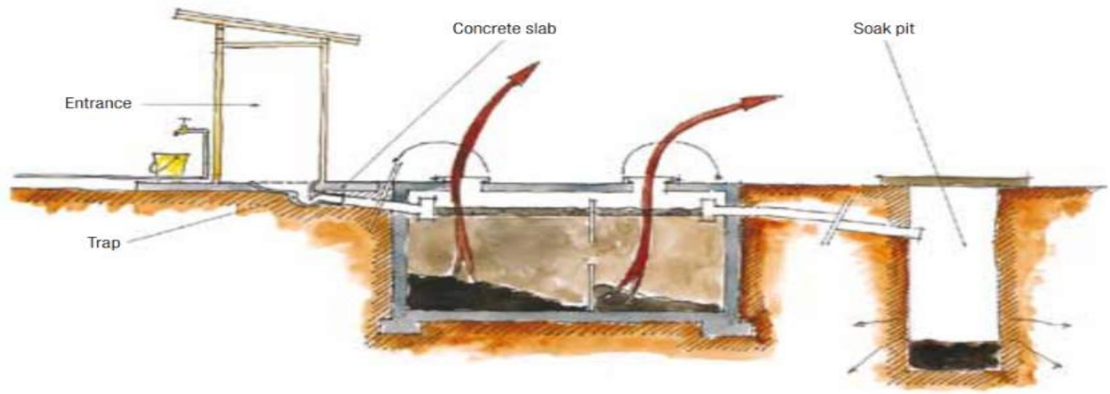


Figure 22 Emptying septage from septic tanks (Source: ICRC)

Quantities of septage to be removed. When emptying septic tanks, ideally only the accumulated faecal sludge is removed when the first chamber of the septic tanks is half full to allow for quiescent settling of human waste. In anaerobic conditions, with degradable cleaning materials, such as toilet paper (which is common in Addis Ababa), this would be 40 litres per capita per year (lcy), see Table 2.

However, complete septic tank emptying provides the opportunity to assess how well the septic tank is functioning, to identify repair needs and issues related to proper operation that might increase the lifespan of the system. Complete emptying in Addis Ababa is also often required because people wait until there are problems e.g., the toilet cannot be flushed because the first chamber is filled with sludge. As the first compartment of a properly designed septic tank is twice the size of the second compartment (see Figure 22) this means, that instead of 40 litres per capita per year, 40 + 50% * 40 = 60 litres septage per capita per year would be removed.

It is to be expected that after a couple of years of a successful emptying campaign, septic tanks will be emptied 'on time', meaning when the first compartment is 50% full. In that case the total volume of septage would be 40 lcy sludge + 40 litres settled water in the first compartment and 40 lcy in the second compartment: total 120 lcy plus some water for cleaning inside the tank, once empty. We have selected the average between 60 and 120 being **100 litres per capita per year** for the removal of septage.

4.4. Sanitation and wastewater

To be able to assess to design an operational mechanism for faecal sludge management, we prepared a possible scenario for Addis Ababa for the period 2021-2050. We assumed that:

- Open Defecation will be abandoned by 2030 the timeline for the Sustainable Development Goals;
- In line with the SDGs all sanitation systems will be managed adequately and all septage and all faecal sludge is being removed on-time.

The estimations on the volume of septage and faecal sludge are presented in Table 3 and Figure 23. The relative division is presented in Figure 24.

Table 3 Estimates volume of faecal sludge and septage Addis Ababa 2021-2050 (Source: WWX, 2021)

Description	units	2021	2025	2030	2040	2050
total sewer & decentralized connections	hh	183,220	243,672	327,414	474,361	623,388
Coverage off-site	% pop	18%	20%	22%	23%	22%
% open defecation	% pop	10%	5%	0%	0%	0%
% onsite	% pop	72%	75%	78%	77%	78%
% onsite wet systems as % onsite	%onsite	20%	30%	40%	65%	90%
% onsite dry systems as % onsite	%onsite	80%	70%	60%	35%	10%
Onsite wet systems	hh	140,000	270,000	460,000	1,040,000	1,960,000
Onsite dry systems	hh	570,000	630,000	690,000	560,000	220,000
%onsite as part of total population	%total pop	71%	75%	78%	77%	78%
Basic assumptions						
Sludge from sewerage to be managed per year	lcy	25	25	25	25	25
Septage to be managed per year	lcy	100	100	100	100	100
Sludge accumulation dry systems	lcy	60	60	60	60	60
Potential for reuse						
Effluent WWTPs	m3/day	61,073	86,040	111,321	161,283	211,952
Sludge from WWTPs to be managed per year	m3/year	4,581	6,092	8,185	11,859	15,585
Willingness to empty onsite wet		100%	100%	100%	100%	100%
Septage to be managed per year	m3/year	70,000	135,000	230,000	520,000	980,000
Faecal sludge from pits per year	m3/year	171,000	189,000	207,000	168,000	66,000
Willingness to empty onsite dry		10%	50%	100%	100%	100%
Faecal sludge from pits to be managed per year	m3/year	17,100	94,500	207,000	168,000	66,000

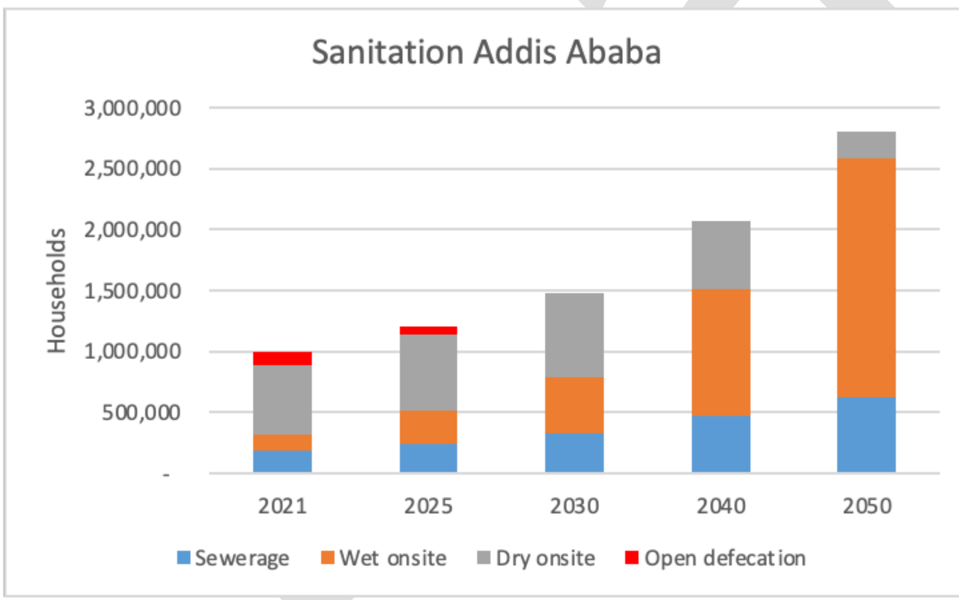


Figure 23 Projection sanitation Addis Ababa 2021-2050 in terms of households (Source: WWX, 2021)

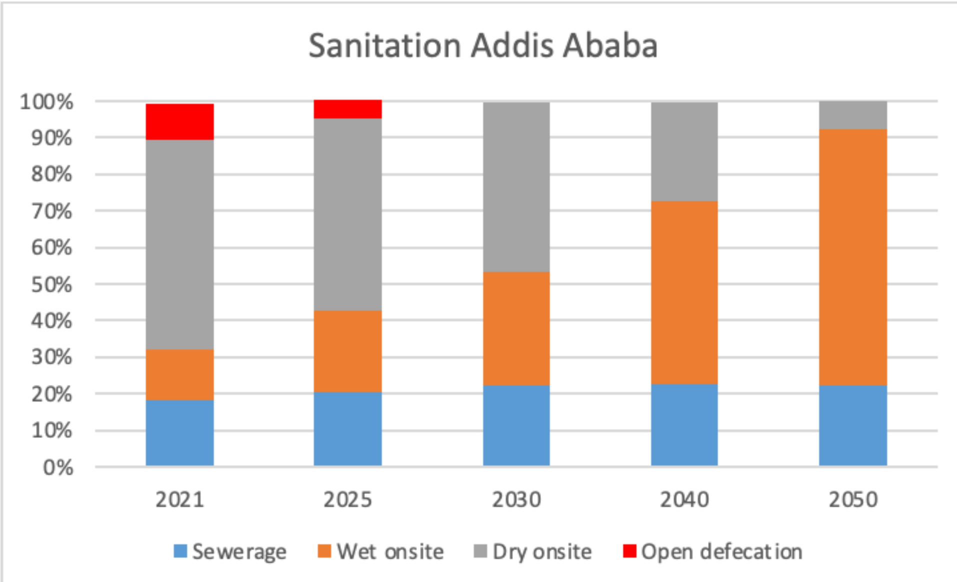


Figure 24 Projection sanitation Addis Ababa as % 2021-2050 (Source: WWX, 2021)

4.5. Faecal sludge and septage emptying and transport

4.5.1. Criteria for selection of appropriate technologies for emptying and transport

The criteria used for the selection of appropriate technologies for emptying and transport are:

1. **Proven technologies:** this means the technology has been applied widely and can be purchased from reliable and certified suppliers;
2. **Innovative technologies that have successfully been trialled in Ethiopia or neighbouring countries**. Hence, only innovations that are 'fit' to handle 'difficult' sludge from difficult locations are considered. 'Difficult sludge' means relatively thick sludge full of rubbish. Difficult location means small unpaved access lanes in hilly terrain;
3. **Sustainable or potentially sustainable technologies:** the technology should be affordable to local entrepreneurs and able to be operated and maintained in Addis Ababa;
4. Technologies that **increase households' service level** (time, hygiene, costs, value for money, etc.);
5. Technologies that **improve the wellbeing and working conditions of the workers**;
6. Technologies that **protect groundwater**;
7. Technologies that **increase service level from pit emptier point of view** (hygienic, reduced workload, assists in removal/ transport of rubbish, reduced smell, etc.

4.5.2. Selection of appropriate technologies and equipment for emptying and transport

4.5.2.1. Characteristics of OSS to be served

From a technical point of view, the main parameters which determine the necessary emptying and transport equipment are:

(i) Septage/faecal sludge **composition** (solid waste contents[2] and viscosity class[3]);
(ii) **Accessibility** of the onsite systems, which can be reflected by the distance between latrines and the nearest paved road.

Based on these parameters, onsite systems can be divided in 3 categories:

- **Category 1:** septic tanks;
- **Category 2:** accessible pit latrines (considered to be less than 30 metres from a paved road accessible by a Mechanical Desludging Unit (MDU);
- **Category 3:** Inaccessible pit latrines considered to be more than 30 metres from a paved road accessible by an MDU.

See Table 4 for the main design parameters for each of these categories.

Table 4 Main design parameters for FS handling equipment in Addis Ababa

Onsite sanitation category	Storage	Sludge characteristics		Accessibility
		Viscosity class	Solid wastes	Distance from nearest paved road
Septic Tank	Septic tanks and soakaways	low$^-$ % $H_2O \geq 98$ % % TVS ≤ 1 % (of wet weight)	Low contents	< 30 meters
Pit Latrine accessible	(Ventilated Improved) Pit latrines	low$^-$ to low-low$^+$ %H_2O: 85 - 93% %TVS: 3.5 - 7.5% (of wet weight)	High contents	< 30 meters
Pit Latrine inaccessible				> 30 meters

Figure 25 shows that vacuum systems with airflows of 5m^3/min and relative vacuum of 0.7bar might be suitable to empty both septic tanks and accessible pit latrines in Addis Ababa. For pit latrines, fluidization might be required as sludge viscosity class might often be close to med. – med$^+$.

For larger distances, stronger suction performances will be required with relative pressure up to 0.8bar and airflows up to 10m^3/min which will require larger vacuum units. In practice, vacuum emptying of inaccessible pit latrines will only be possible with high end vacuum pumps where O&M might be far too complicated and expensive for the Addis Ababa context.

These findings will be considered for the following preselection of technologies (section 4.5.2.2).

[2] *FSM tools, Data collection instruments (WSP, 2016) established a classification for solid waste content of sludge from "no solid waste contents", to "Very high solid waste contents".*

[3] *Bosh et al. (1985) established that the flow behaviour and hence "pumpability" of faecal sludge can be determined by analysing its composition in terms of water and volatile content. Flow behaviours can be classified based on four viscosity classes: low$^-$, low-low$^+$, med-med$^+$, high-high$^+$.*

Distance				
	100 m -150 m			
	60 m -100 m	p = 0.8 bar a = 2 – 10 m³/min		
	15 m – 60 m	p = 0.8 bar a = 2 – 10 m³/min	p = 0.8 bar a = 15 – 25 m³/min	p = 0.8 bar a = 25 – 35 m³/min
	0 – 15 m	p = 0.5 bar a = 2 – 10 m³/min	p = 0.5 bar a = 15 -25 m³/min	p = 0.5 bar a = 25- 35 m³/min
p = rel. vacuum (bar) a = airflow (m3/min)		low$^-$ to low$^+$	med. to med$^+$	high$^-$ to high$^+$
		Viscosity		

Vacuum system
Pneumatic conveying system
Remote system

Figure 25 Matrix for suction equipment selection (Source Bösh et al., 1985)[4].

4.5.2.2. Preselected technologies

Emptying and transport. To date, vacuum tankers are the most used equipment for onsite system emptying. In Addis Ababa: private FSM operators generally use second hand vacuum trucks from Europe and Japan; AAWSA uses new trucks. Their limited suction performance and/or large size make them less appropriate when thick sludge from pit latrines must be pumped over large distances (> 15 meters) in narrow areas, but this is compensated by instructing the household to add large volumes of water so that the sludge becomes pumpable.

Over the last few years two organisations have experimented with emptying alternatives such as:

- **Bajaj transporting small vacuum tanks (Emanuel NGO):** small vacuum tanks that can be transported in narrow areas to serve difficult-to-access pit latrines;
- **Vacuum tank + High Pressure washer**: combination of vacuum and jetting tools commonly used for sewer maintenance in northern countries, and which are experimented today to develop pit latrine emptying services in Ethiopia, Malawi, and Kenya. WASTE in cooperation with ViaWater Ethiopia has manufactured the 'ROM' locally. The ROM was imported from the Netherlands in Malawi and Kenya. The idea of using a high-pressure washer is based on using one of the properties of sludge called thixotropy: "Thixotropy is the property of certain gels or fluids that are thick (viscous) under normal conditions, but flow (become thin, less viscous) over time when shaken, agitated, or otherwise stressed".

The ViaWater sponsored MDU is published online: https://aquaforall.org/viawater/projects/ethiopia-mobile-desludging-device.html. The factsheet is presented in Annex 3 – Fact sheet MDU WASTE / ViaWater Ethiopia,

[4] This table is valid for level sites only, 100 mm diameter hoses and a max. pit depth of 3 meters. With vacuum systems, the pumping hose inlet is kept submerged in the sludge which is sucked into the hose by the atmospheric pressure. Pneumatic conveying occurs when particles of sludge are carried by a large flows air stream. Remote systems are portable vacuum drums connected to larger vacuum units which can get close to latrines pits in narrow areas.

Details on other technologies can be found in the publication: “*FSM: Systems Approach for Implementation and Operation”*, edited by EAWAG 2014 (EAWAG, 2014). Details on the experiences with the MDU can be found in the publication *“Testing and developing of desludging units for emptying pit latrines and septic tanks, Results of nine months field-testing in Blantyre – Malawi”* prepared by WASTE Advisers and the NL Red Cross in 2014 as part of the Emergency Sanitation Project (ESP) and the S(P)EEDKITS Project. The ESP project is funded by the US Office for Foreign Disaster Assistance (OFDA) and is a consortium of the International Federation of Red Cross and Red Crescent Societies (IFRC), WASTE and Oxfam GB.

Figure 26 Bajaj (Emmanuel, Addis Ababa, 2021, https://edaethiopia.org) and MDU (WWX Nakuru, 2019)

In Table 5 the main proven technologies for septage and faecal sludge emptying, and transport have been listed and their potential application scope for each onsite sanitation category assessed.

Table 5 Potential scope of service for the different emptying and transport technologies in Addis Ababa

Emptying	Transport	Transfer	Septic Tank	Access-ible PL	Inaccess-ible PL
Modified garden tools	3-wheel / light truck	Barrels	-	✓	✓
Bajaj with 2m^3 tank	3-wheeler Bajaj	Tank	✓	✓	-
Motorized / hand diaphragm pump	Tractor	Tank trailer	✓	-	-
eVac	Light truck	Barrels	-	✓	✓
Vacuum tank	Truck	Tank	✓	-	-
Slurry tanker + HP washer	Tractor	Tank	✓	✓	-
Vacuum tank + HP	Truck	Tank	✓	✓	-
Mechanical Desludging Unit	Tractor or Truck	Tank	✓	✓	✓

Legend: - not applicable or not efficient ✓: applicable

Transfer stations. Depending on the average transport time from onsite sanitation systems to FSTPs, transfer stations can be useful to reduce operations costs by increasing transport capacity to the FSTP. There are two main types of transfer stations: 'fixed' and 'mobile':

- **Fixed transfer stations** include vault-like concrete structures and various storage devices made of plastic materials and/or metallic materials as well as network-connected stations which consist in faecal sludge discharging points into the sewerage network;
- **Mobile transfer stations** can consist in a large platform / tank placed on a chassis with wheels that can be pulled by a tractor and where MDUs or plastic drums can be discharged. Once the full capacity is reached, the transfer station is hauled to the FSTP for discharging.

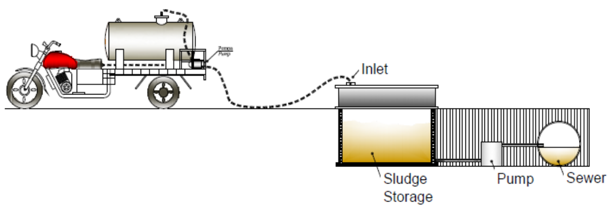


Figure 27 View of 2 transfer stations. On the left, a septage discharge station connected to the sewer (Source: MottMacDonald), on the right a 10m³ tank mounted on a chassis in Nakuru (Source: WWX).

The main proven technologies for faecal sludge transfer have been listed, and the feasibility of using them for each onsite sanitation category is assessed in Table 6.

Table 6 Potential scope of service for the different transfer stations

Transfer	ST	PL_{acc}	PL_{inacc}
Sewerage connected stations	✓	-	-
$5m^3$ tank mounted on a chassis	-	✓	✓

Legend: **-** *not applicable or not efficient* ✓ *: applicable*

Sewerage-connected stations could be adapted to evacuate septage from areas located far from FSTPs. Depending on the sewer design, transport of septage through sewer lines can be a cost-efficient option. Faecal sludge from pit latrines cannot be discharged into sewer lines as their high waste and solids contents would impact negatively on the sewer system maintenance. Mobile transfer stations could be adapted to informal / high density areas located far from FSTPs.

4.5.2.3. Selected technologies

Based on the literature review and WWX practical experience from Kenya, Zambia and Malawi, assessment of appropriateness of emptying, transfer and transport technologies has been carried in Table 7 using a combined rating / traffic light system to indicate whether the technologies were fitting criteria defined in section 4.5.1. Green (+1) means "fits completely", orange (0) "fits partially" and red (-1), "unlikely to fit". Within column "T", the average rating is calculated by dividing the sum of the ratings by the number of applicable criteria. The highest values resulting are highlighted with a green.

Emptying and transport

Table 7 Screening suitability of emptying and transport technologies

On-site-san.	Emptying	Transport	Selection criteria							
			1	2	3	4	5	6	7	T
Septic Tan	Diaphragm handpump	Tractor + tank trailer	0	NA	1	-1	-1	1	-1	-0.17
	Trash pump	Tractor + tank trailer	0	NA	1	-1	-1	1	-1	-0.17
	Motorized diaphragm pump	Tractor + tank trailer	0	NA	1	-1	-1	1	-1	-0.17
	Vacuum tank	Truck	1	NA	1	0	0	1	0	0.50
	Slurry tanker + HP	Tractor	0	NA	1	0	0	1	0	0.33
	Vacuum tank + HP	Truck	1	NA	1	0	0	1	0	0.50
Access-ible pit latrines	Modified garden tools	3-wheeler / light truck	0	NA	1	0	0	1	0	0.33
	Bajaj	3-wheeler	1	1	1	1	1	1	1	1.00
	Evac	Light truck	0	0	1	0	0	1	1	0.50
	Slurry tanker + HP	Tractor	0	NA	1	1	1	1	1	0.83
	Vacuum tank + HP	Truck	1	NA	1	1	1	1	1	1.00
	MDU	Tractor / Truck	1	1	1	1	1	1	1	1.00
In-access-ible pit latrines	Modified garden tools	Pushcarts	0	NA	1	0	-1	1	0	0.17
	Modified garden tools	3-wheel / light truck	0	NA	1	0	0	1	0	0.33
	Modified garden tools	Tractor + tank trailer	0	NA	1	0	1	1	0	0.5
	MDU	Tractor / Truck	1	1	1	0	1	1	0	0.71
	Evac	Light truck	0	0	1	0	0	1	0	0.33

Regarding septic tanks, the current vacuum trucks are well adapted and couldn't be improved by using any alternative pumping systems. Moreover, addition of an HP washer isn't needed as it will not increase the service level. Bajaj, MDUs and vacuum tankers are the best technology for accessible pit latrines as long as those are used in combination with a high-pressure washer to fluidize thick sludge to make it "pumpable".

For inaccessible pit latrines, the MDU appears as the best option. As the MDU is relatively small, a transfer station is needed in areas far away from the FSTP.

This assessment concluded on the selection of the equipment presented in Table 8.

Table 8 Selected emptying and transport technologies

Onsite sanitation system	Emptying	Transport	Service Provider
Septic tank	Vacuum tank	Truck	Vacuum tank operator
Accessible pit latrine	Bajaj	3-wheeler	Mechanical Desludger
	Vacuum tank + HP washer	Truck	
	MDU	Light Truck / Tractor	
Inaccessible pit latrine	MDU	Light Truck / Tractor	Mechanical Desludger

Transfer stations

Table 9 Selected transfer stations technologies

OSS category	Transfer	Criteria						
		1	2	3	4	5	6	7
Septic tanks	Network-connected stations	1	NA	1	NA	NA	NA	1
Accessible and inaccessible pit latrines	5m^3 tank mounted on a chassis	1	NA	1	1	1	1	1

Network-connected stations are appropriate transfer technologies for septage from septic tanks. Transfer of sludge from pit latrines into larger conveyance devices will generate additional handling procedures which should be balanced with transportation benefits.

4.5.2.4. Selected equipment

Equipment selection is mainly based upon a consideration of investment and O&M costs as well as local availability of spare parts and experienced mechanics. Unit capital costs of emptying and transport equipment needs updating and verification. Preliminary unit costs are presented in Table 10.

Table 10 Indicative capital costs of emptying and transport equipment

Technology	Product	Specifications	Indicative Cost (Euro)
Vacuum truck	Brand new Brand: Hydrovide Suction only 6 m^3 capacity	Origin: Europe 200 HP truck Renault 320 m^3/h vacuum pump	€ 120,000
	Brand new Brand: SPV	Origin: China 100 HP truck Foton	€ 23,000

Technology	Product	Specifications	Indicative Cost (Euro)
	Suction only 3 m^3 capacity	100 m^3/h vacuum pump	
	Used truck Suction only 2 - 6 m^3 capacity	Origin: Japan	€ 20,000
Bajaj	Brand-new Brand: Bajaj 2m^3 capacity (sludge)	Origin: India	€ 3,500
MDU manufactured in Ethiopia	Brand-new Suction & High Pressure Tractor: TAFE S. tanker: 3 m^3	Origin tractor: India 75 HP, 2WD	€ 15,000

Based on this, we can conclude that:

- **For septic tank emptying,** second-hand vacuum tanks are preferred to new ones as local operators already manage to import and maintain those at a substantially lower price. From a technical point of view, second-hand trucks are suitable to empty thin sludge as the FS from septic tanks in Addis Ababa. New vacuum trucks manufactured in China are getting more and more affordable, and some (like Sinotruck) are already used in Addis Ababa. If more vacuum trucks are required, purchase of new Chinese trucks would have to be considered;
- **For accessible pit latrine,** Bajaj is the cheapest option. Alternatively, second hand vacuum tanks with HP washer for sludge fluidization are the cheapest options. As strong suction performance is required to empty pit latrines brand new vacuum units are to be preferred option. It has been assessed that a 3 m^3 vessel would be optimal to ensure close access to pit latrines, offer good level of service (with emptying period from 2 to 7 years depending on HH size). This will foster the development of emptying services dedicated to pit latrines. 1 m^3 MDUs will often be too small to be competitive on the ST emptying market;
- **For inaccessible pit latrines,** the MDU developed with ViaWater is advised.

The selected emptying and transport equipment is summarized in Table 11.

Table 11 Selected emptying and transport equipment and their indicative costs

OSS category	Equipment	CAPEX (Euro)	OPEX (Euro/m³/km)
Septic Tanks	Second-hand 6m^3 vacuum tank from Japan / EU	€ 20,000	€1
Accessible pit latrines	Second-hand 6m^3 vacuum tank from Japan / EU with high pressure washer	€ 20,000	€1.5
Inaccessible pit latrines	MDU manufactured in Ethiopia	€7,500	€2

5.Offsite sanitation

Now, around 60,000m3/day of wastewater is collected and conveyed in sewerage systems and treated in wastewater treatment plants. This is expected to grow to more than 200,000m^3/day in 2050, see Table 12.

Table 12 Projections off-site systems in Addis Ababa 2021-2050 (Source: WWX, 2021)

Description	units	2021	2025	2030	2040	2050
Sewer connections Kality						
% Sewerage connections	% conn	15%	18%	20%	21%	21%
Sewer connections	hh	150,000	210,552	294,118	441,176	588,235
Return ratio	% dw	72%	80%	80%	80%	80%
Discharge into WWTP Kality	m3/d	50,000	75,000	100,000	150,000	200,000
Sewer connections Kotebe						
% Sewerage connections	% conn	3.3%	1.8%	2.2%	1.6%	1.2%
Sewer connections	hh	33,000	33,000	33,000	32,353	32,353
Return ratio	% dw	72%	75%	80%	80%	80%
Discharge into WWTP Kotebe	m3/d	11,000	11,000	11,220	11,000	11,000
Decentralized systems						
% Sewerage connections	% conn	0.0220%	0.010%	0.020%	0.040%	0.100%
Sewer connections	hh	220	120	296	832	2,800
Return ratio	% dw	72%	75%	80%	80%	80%
Discharge into decentralized WWTP	m3/d	73	40	101	283	952
total sewer & decentralized connections	hh	183,220	243,672	327,414	474,361	623,388
Coverage off-site	% pop	18%	20%	22%	23%	22%
Effluent WWTPs	m3/day	61,073	86,040	111,321	161,283	211,952
Sludge from WWTPs to be managed per year	m3/year	4,581	6,092	8,185	11,859	15,585

The remainder of the 49million m^3 of wastewater that is annually generated in the city of Addis Ababa is discharged into the rivers and streams flowing through the city, like the Akaki River. AAWSA has two wastewater treatment plants in Addis Ababa, the Kality WWTP and the Kotebe WWTP. Both are in southern Addis Ababa. See map in Figure 28.

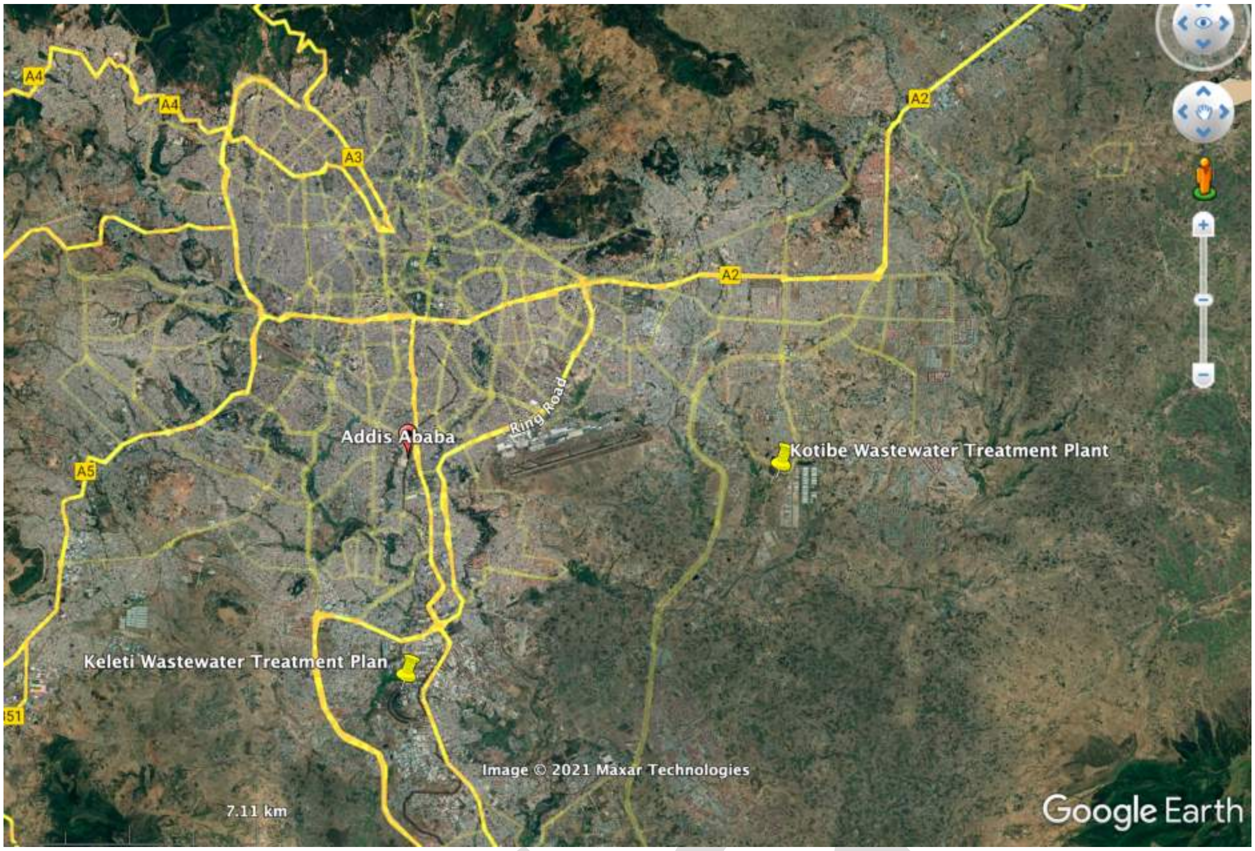


Figure 28 Map of Addis Ababa showing location 2 WWTPs (Google Earth, accessed 10 November 2021)

5.1. Kality Wastewater Treatment plant

The Kality wastewater treatment plant was formerly designed for a maximum capacity of 7,500m^3/d of wastewater but due to the increase of the population of Addis Ababa City and provision of water supply and other socio-economic developments, the operating capacity went beyond its design limit. As a result, sewage waste overflew on to streets and into the water courses. To alleviate this problem, AAWSA embarked to redesign and rehabilitate the existing wastewater facility. AAWSA hired Morrison Hershfield, a Canadian consultant firm to design a new plant funded by World Bank and hired Aktor from Greece to construct the plant. Beles Engineering PLC conducted the Environmental and Social Impact Assessment (ESIA) and Arma the engineering work. Currently the Operation and Maintenance is outsourced to a Chinese firm.

The design treatment capacity for the new treatment plant is 100,000m^3/day. Currently, 150,000 customers are served which benefits or 750,000 people. 50,000m^3 is being treated daily. In future, around 600,000 customers are to be connected and 200,000m3/day to be treated. See details in Table 13.

Table 13 Planning sewerage Kality WWTP (Source: WWX, 2021)

Description	units	2021	2025	2030	2040	2050
Sewer connections Kality						
% Sewerage connections	% conn	15%	18%	20%	21%	21%
Sewer connections	hh	150,000	210,552	294,118	441,176	588,235
Return ratio	% dw	72%	80%	80%	80%	80%
Discharge into WWTP Kality	m3/d	50,000	75,000	100,000	150,000	200,000

The Kality Wastewater Treatment plant comprises a centralized and integrated sewer collection system and a single WWTP.

The WWTP includes the following unit processes:

- Intake
- Fine screening
- Grit removal
- Primary clarifiers
- Up flow anaerobic sludge blanket (UASB) process
- Trickling filter (TF) process
- Secondary clarifiers
- Constructed wetland treatment
- Sludge Digesters
- Sludge drying
- Sludge disposal

The Kality wastewater treatment system is schematically presented in Figure 29.

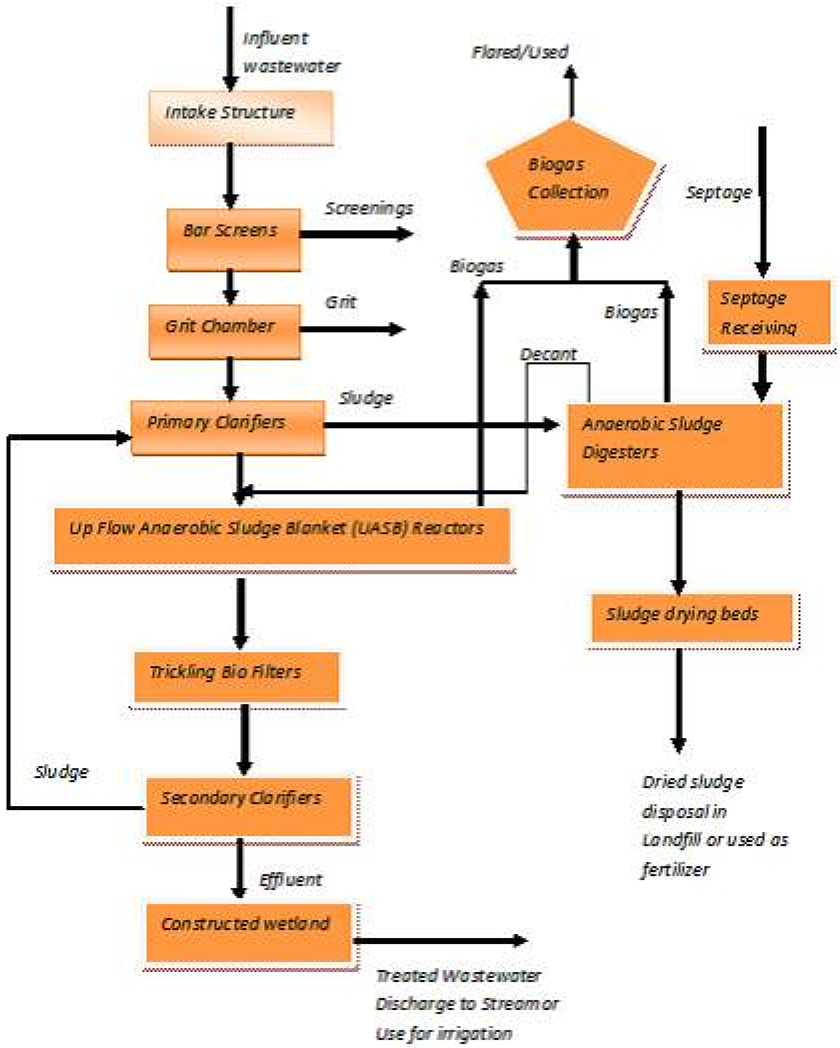
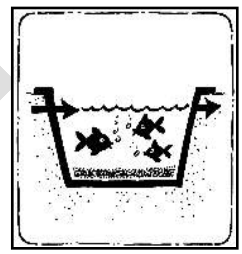


Figure 29. The Kality WWTP treatment system

The biogas produced in the WWTP is currently being flared, whereas this could have been used to generate electricity to be used for the pumps of the WWTP. The potential for electricity production and the financial implications are presented in Table 14. The 8,000m^3/day biogas produced currently could produce almost 7 million kWh/year. Assuming a GenSet could be purchased at €800,000, this investment could be earned back in 2.4 years. See calculation and assumptions in Table 14.

Table 14 Calculation of the potential to generate electricity from biogas at Kality WWTP (Source: WWX, 2021)

Generate electricity from Biogas UASB Kality				
Description	**Unit**	**2021**	**2030**	**2040**
Daily Capacity	[m3/day]	50,000	100,000	150,000
Gas production	[m3/day]	8,000	15,000	22,000
Methane content biogas	[% biogas]	58%	58%	58%
Biogas	[m3/day]	4,640	8,700	12,760
Heating value biogas	[kWh/m3]	10	10	10
Heating value per year	[kWh/year]	16,936,000	31,755,000	46,574,000
Efficiency generator	[%]	40%	40%	40%
Electricity per year	[kWh/year]	6,774,400	12,702,000	18,629,600
Power	[kW]	773	1,450	2,127
Purchase price kWh (factor 60)	[Birr/kWh]	ETB 2.7	ETB 2.7	ETB 2.7
Purchase price kWh (factor 200)	[Birr/kWh]	ETB 10.8	ETB 10.8	ETB 10.8
Exchange rate	[Birr/Euro]	ETB 53	ETB 53	ETB 53
Purchase price kWh (factor 60)	[Euro/kWh]	€ 0.05	€ 0.05	€ 0.05
Purchase price kWh (factor 200)	[Euro/kWh]	€ 0.20	€ 0.20	€ 0.20
Savings for electricity at factor 60	[€/year]	€ 340,000	€ 630,000	€ 930,000
Unit price investment	[€/kW]	€ 1,000	€ 1,000	€ 1,000
Investment biogas GenSet	[Euro]	€ 800,000	€ 1,500,000	€ 2,100,000
Repayment period	[years]	2.4	2.4	2.3



Another unused potential is the use of the effluent. The effluent is reported to fulfil all environmental standards. Hence, this could be used for aquaculture. In Table 15 we calculate that currently, around 18ton fish could be harvested monthly. This could grow to 54ton/month in 2050. The revenues could be between €0.9 and €2.5 million per year. The area required between 2 and 6ha. There is enough land available, see map in Figure 29.

Table 15 Estimates potential aquaculture Kality WWTP

Fish farming in effluent UASB Kality				
Description	**Unit**	**2021**	**2030**	**2040**
Retention time	[days]	7	7	7
Volume	[m3]	29,780	59,559	89,339
Effective depth	[m']	1.50	1.50	1.50
Surface area	[m2]	20,000	40,000	60,000
Surface area	[ha]	2.0	4.0	6.0
BOD removal lower layers	[%]	0%	0%	0%
Remaining BOD	[mgBOD/l]	50	50	50
Breakdown rate BOD 22degr.	[1/day]	0.42	0.42	0.42
BOD effluent	[mg/l]	12.8	12.8	12.8
Efficiency BOD removal	[%]	76%	76%	76%
Fish production	[kg/month]	18,000	36,000	54,000
Sales price fish	***[Euro/kg]***	***€ 4.00***	***€ 4.00***	***€ 4.00***
Revenues fish per year	Euro	€ 864,000	€ 1,728,000	€ 2,592,000

Figure 30 Kality WWTP with land for fishponds (Google Earth, accessed 5 November 2021)

5.2. Kotebe Wastewater and Sewage Treatment plant

Kotebe wastewater and sewage treatment plant receives 4,000m^3 of wastewater per day. The estimated capacity of the plant is 85,000m^3/year. The plant has both onsite connections and offsite condominium connection. The plant also received sludge from vacuum trucks from that empty from septic tanks in the residential areas, see Figure 15. The treatment process in the plant involves circulation of the sewage in various ponds for a period of about 30 days. This is meant to make the Biochemical Oxygen Demand (BOD) of the sludge to fall below 5mgBOD/l. The sludge is then dried in beds with a small portion being used as manure. All the effluent in the plant is evaporated during the dying process. Like the Kality WWTP, the area is not fenced and freely accessible by anybody, see plan in Figure 32. This may lead to unauthorized access and contamination of the public. Hence, it is strongly advised to fence the area and restrict access.

The way the contents of the vacuum trucks is being screened is rather crude and the sidewalls of the ponds erode, see Figure 31. Hence, it would be wise to introduce dedicated dumping/ screening sites.

Figure 31 Erosion of banks of sewage ponds (Source: WWX, 2021)

Like the WWTP Kality, the sludge is collected informally by farmers while there is good potential to add value by co-composting, Black Soldier Fly production or vermicompost. See chapter 6. The plan in Figure 32 shows the layout of the plant.

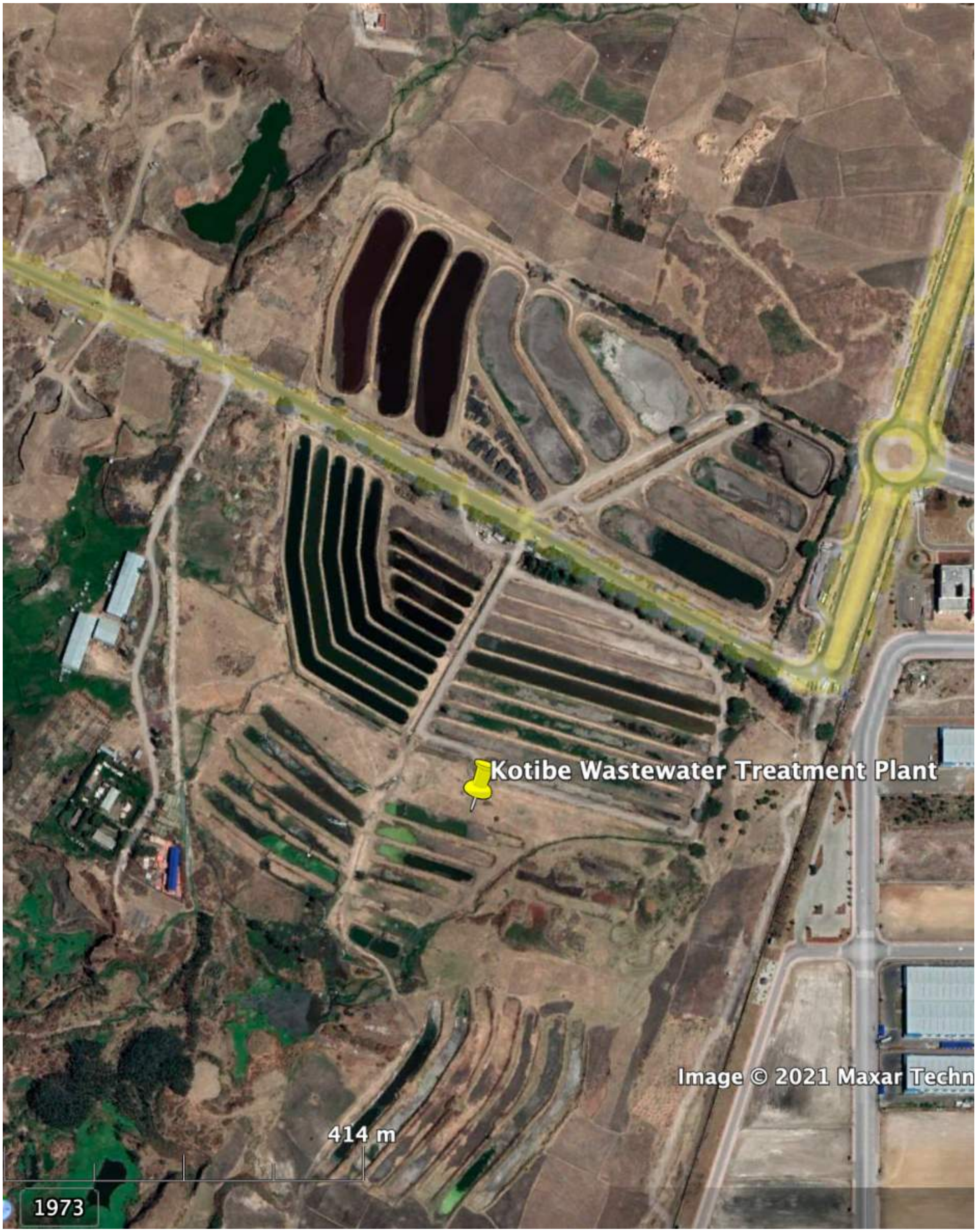


Figure 32 Layout Kotebe WWTP (Google Earth accessed 5 November 2021)

6. Reuse Options

6.1. Introduction

The end products (treated wastewater and faecal sludge) of the sanitation service chain will either be safely disposed-off or re-used for certain applications. On the one hand, safe disposal of treated wastewater and sludge, especially the part which does not provide value for resource recovery for reuse, is critical to ensure isolation of the waste from human and environmental contact. In addition, treated wastewater and faecal sludge contain resources such as nutrients, energy, water, and other products, all of which have intrinsic value and can offer revenue gain for the service provider. Thus, depending on the treatment type and quality and the type of resource recovered, different types of products can be produced from the treated sludge and wastewater.[5]

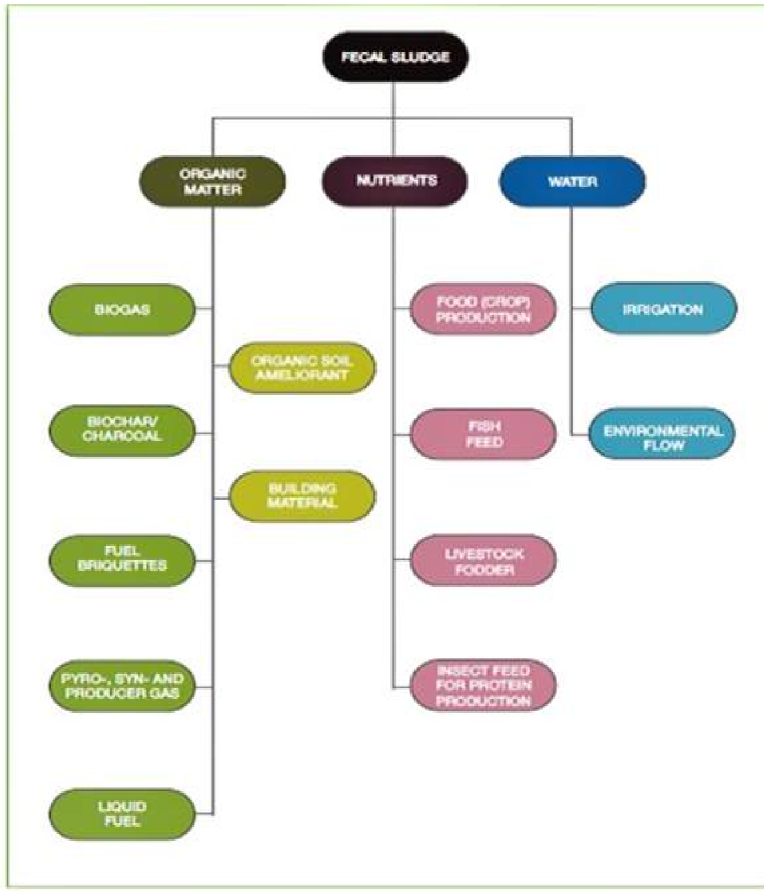


Figure 33 Faecal sludge reuse. Source: Krishna C. Rao, et al (2016), Business Models for Faecal Sludge Management, Resource Recovery & Reuse Series 6, CGIAR Research Program on Water, Land and Ecosystems (WLE), International Water Management Institute (IWMI

The treated wastewater can be used for non-drinking water purposes such as toilet-flushing, gardening, irrigation, construction work, cleaning, and ground water recharge *et cetera*. Treated sludge has been found to have properties superior to those of fertilizers, such as bulking and water retention properties, and the slow, steady release of nutrients. Sludge that has been treated can hence be packaged and be used in agriculture, home gardening, forestry, landscaping, parks, golf courses, mine reclamation, as a dump cover, or for erosion control. Application of sludge on land may be less expensive than disposal. The use or application of treated wastewater and sludge must however comply with the established water and effluent quality standards. Following appropriate safety and application regulations is thus critical for effective reuse[6] . Figure 33 provides a comprehensive overview of the options. In the following sections we describe the reuse options most relevant to Addis Ababa:

- Biogas, see section 6.2;
- Reuse of effluent, see section 6.3;
- Black Soldier Flies, see section 6.4;

[5] NAWASSCO Onsite Sanitation Services (Oss) Business Model
[6] Ibid

- Biosolids, see section 6.5;
- Co-compost, see section 6.6;
- Non-carbonise biofuel, see section 6.7;
- Carbonized biofuel, see section 6.8;
- Vermicompost, see section 6.9.

6.2. Biogas

Biogas is generated when bacteria degrade biological material in the absence of oxygen; in a process known as anaerobic digestion. Since biogas is a mixture of methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide and traces of water vapour. It is a renewable fuel produced from waste treatment. Anaerobic digestion is basically a simple process carried out in several steps by many different bacteria that can use almost any organic material as a substrate - it occurs in digestive systems, marshes, rubbish dumps, septic tanks, and the Arctic Tundra. Biogas is a gas produced from organic materials such as animal manure, human excreta, kitchen remains, crops straws, and leaves after decomposition and fermentation under airtight (no oxygen) conditions. Main products of the anaerobic digestion are biogas and slurry. After extraction of biogas (energy), the slurry comes out of the digester as a by-product of the anaerobic digestion system. The main constituents of biogas are the CH_4, and CO_2 gas. The biogas burns very well when the CH_4 content is more than 50% and therefore biogas can be used as a substitute for kerosene, charcoal and firewood for cooking and lighting.

The potential to convert the biogas at the Kality WWTP has been calculated in section 5.1. In addition, the following can be envisaged:

- AAWSA can use biogas generated from their own wastewater to power their operations. This will allow the utility to reduce the consumption of electricity. It must be stressed that the sewage treatment plant's primary function -- removing pollutants and disease-causing pathogens -- is not interrupted by this feature;
- AAWSA could also claim carbon credits under the clean development mechanism. Achieving even better results are possible through close monitoring and control of processes. Dedicated efforts by the technical support team ensure consistent operations of the plant for not only achieving the desired parameters but also sustain green energy production from non-fossil sources which helps protect the environment;
- The excess power, if any, can be used to incinerate solid waste materials finding its way to the treatment plant. A closed loop incineration system will need to be considered to minimize ash, heat, and gas to be dissipated into the surrounding environment;
- AAWSA will need to work closely with EPA to ensure conformity to the environmental regulations;
- Kaliti WTP design made provision for expansion of the same type of treatment process to 200,000m^3/day in the same location. It is recommended that AAWSA studies whether it could become a power producer and effectively engage gradually with the Ethiopian Electric Power (EEP) to discuss the possibility to enter into a Power Purchase Agreement (PPA) in which the utility gets paid for the electricity produced. Prior to this, AAWSA will need to conduct a feasibility study to determine the commercial viability and requirements for setting up power infrastructure;
- Bottling of Gas: In future AAWSA could explore the viability of bottling biogas. The technology is evolving and certainly might become a new revenue stream.

6.3. Effluent reuse

Apart from the aquaculture mentioned in section 5.1, effluent from WWTPs can be used in several other ways including in farm Irrigation, hydroponics, landscaping, tree nurseries, sustainable tree planting, construction, carwash and non-portable water processing plants. Treated wastewater is widely applied in the world, especially in areas where there is increased scarcity of alternative water for irrigation, increased urban demand for potable water, high cost of (artificial) fertilizer and high cost of advanced wastewater treatment. There is a huge market potential for effluent re-use in the Oromia region. However, these initiatives are sustainable only when there are large volumes of effluent. It is also important to consider the costs versus benefits in reuse of effluent from treated sanitation waste. The target customers who are likely to find viable reuse options for effluent from treated faecal sludge and waste need to be considered.

6.4. Black Soldier Fly (BSF)

Based on the analysis of various waste recycling methods, BSF emerges as a very viable method of bioconversion of organic waste that can engage in with a short turnaround period to generating revenue. BSF larvae have the capacity to convert various sources of organic waste and can have a higher faecal sludge utilization as compared to the fuel production by briquettes thus touching on SDGs on environment, agriculture, water and sanitation and clean cities. The main products of the BSF are the larvae, which are a good protein source for monogastric animals like chicken, fish, and pigs. They can either be fed to the animals in their raw form as larvae or processed further and integrated into animal feeds. BSF, or *Hermetia illucens* is a common and widespread fly of the family *Stratiomyidae*. BSF is a fly that does not hold any disease. Black soldier fly larvae play a similar role to that of redworms as essential decomposers in breaking down organic substrates and returning nutrients to the soil. A commercial case can be advanced for rearing BSF, as the the investment can be done in a modular manner.

6.5. Biosolids production.

Biosolids are the most basic form of reuse of faecal sludge. They are intended to be used as a soil conditioner. Typically, biosolids are removed from a drying bed and after an appropriate processing time can be used directly for land application. Biosolids are typically nutrient rich and can be used as a nitrogen-based fertiliser. They improve soil physical properties, such as moisture holding capacity, aggregation, porosity, and tilth. Hence, their main value is a soil conditioner. Stabilised biosolids provide a slow release of nutrients that can be used by plants over the course of several years. Biosolids can be sold loose or in a pelleted form (loose form is typically used by bulk purchasers, while household customers may prefer waste in neat, compressed pellets). During pelletisation binding material can be used. The binder limits breakdown of the pellets until they are applied to the soil and is relevant when the material is difficult to pelletize. For unrestricted use in agriculture, biosolid pellets need to be sanitized, for instance in greenhouses to assure die-off of all pathogens. Otherwise, the use needs to be restricted to entrenchment: the application of pellets in a trench in agriculture for crops that come not into direct contact with the pellets (bananas, papayas, wheat, etc.).

Figure 34 Biosolid pellets in Kampala (Jan Spit, 2016)

6.6. Co-compost

Compost consists of decomposed organic matter or humus that can be applied to soil for both water retention and nutrient provision purposes. The co-composting process employs controlled aerobic degradation of organics, using more than one feedstock (human waste and organic solid waste). The co-composting process is illustrated in Figure 35. Faecal sludge is rich in nitrogen and therefore does not always satisfy the C/N ratio requirement which leads to high N losses during composting or insufficient temperature increase during the thermophilic composting stage. To minimize this phenomenon, it is advisable to compost faecal sludge with carbon-rich waste. The type of added material will affect the duration of the co-composting. Typically, with market waste, the minimum duration is three months, while with sawdust, it reaches four months. In addition, incoming organics should not have contaminants that negatively affect environmental and human health in the long term.

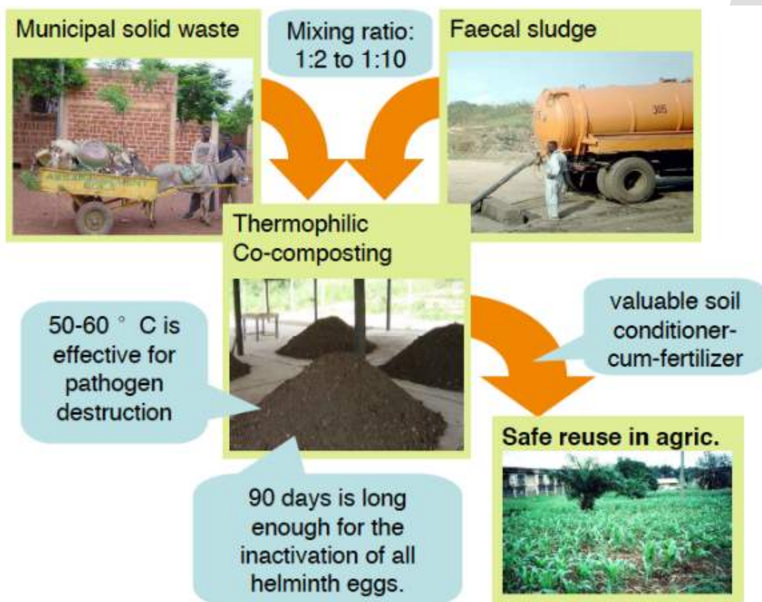


Figure 35 Co-composting process (Sandec, 2008)

In our discussions with WaterAid on 5 November 2021, we were informed that WaterAid is currently working on a co-composting plant, not far from Addis Ababa. We recommend keeping a close watch on the experiences.

6.7. Non-carbonised biofuel

Non-carbonized fuels are made from waste materials that are partially decomposed and then dried to a low moisture content. These fuels can be sold loose or can be pressed by mixing the feedstock with water and a binder and drying it. Non-carbonized fuels burn with a lot of smoke and result in a lot of ash. As such, these fuels are not ideal for household level customers and are more appealing to industries for use in a boiler, kiln, or incinerator. The ash that remains (expected to be about 10% of treatment volume) can be used as an input for construction material.

In Addis Ababa, cement factories represent a strong industry to sell biofuel to, given that they are one of few non-food producing industries that requires solid fuel. Large cement factories burn tens, or hundreds of tonnes of coal per day in the cement production process, often at a high expense. interviews as part of this study. International operating industries such as Lafarge have a global mission to diversify feedstocks. Testing would be required to ascertain the calorific values of biofuel. Previous studies have shown values in the range of 16-24 MJ/kg of dry solids (Alakangas, 2007).

Dried sludge from a conventional or faecal sludge treatment works can be used as an input to this process; alternatively, a specific treatment process can be devised that explicitly aims to produce fuel as the core output. Pivot in Rwanda developed a somewhat complex treatment process, specifically designed from the sludge input stage. Should dried human waste from a STP or FSTP in Addis Ababa be incorporated, the dried sludge from the sludge drying beds could be dried further in greenhouses. In Kigali, the sludge was dried to 80% total solids. By means of thermal drying, the total solids are raised to 95%. Adding a complex and expensive thermal drier would render the process unsuitable for Addis Ababa. See Figure 36 for an impression. The SANIVATION factory in Naivasha, Kenya, produces large briquettes from biofuel on a large scale.

Figure 36 Greenhouse with sludge drying in Kigali (Jan Spit, 2016)

6.8. Carbonized fuel

Carbonized biofuel from human waste can be pure human waste or blended with an organic waste feedstock. For the purposes of this assignment, 'pure' charcoal is assumed to have 100% faecal sludge as the sourcing of organic waste for blending will be a challenge. The process is done in a pyrolizer requiring an energy source. Pyrolysis is a thermochemical treatment where material is exposed to high temperature, and in the absence of oxygen goes through chemical and physical separation into different molecules. The NAWASSCOAL briquette factory in Nakuru, Kenya, produces carbonized fuel on a large scale.

6.9. Vermicomposting

Vermicompost is the product of earthworm digestion and aerobic decomposition using the activities of micro- and macro- organisms at room temperature. Vermicomposting produces a rich organic soil amendment containing a diversity of plant nutrients and beneficial microorganisms. Red worms can be used as feed for chicken or fish while the compost can be sold as a soil amendment (Rodale Institute). There are two main methods of large-scale vermicomposting, windrow and raised bed. Some systems use a windrow, which consists of bedding materials for the earthworms to live in and acts as a large bin; organic material is added to it. Although the windrow has no physical barriers to prevent worms from escaping, in theory they should not, due to an abundance of organic matter for them to feed on. Often windrows are used on a concrete surface to prevent predators from gaining access to the worm population. The second type of large-scale vermicomposting system is the raised bed or flow-through system. Here the worms are fed an inch of "worm chow" across the top of the bed, and an inch of castings are harvested from below by pulling a breaker bar across the large mesh screen which forms the base.

6.10. Estimation of volumes of reuse products (actual, short, medium, and long-term) and selection of most appropriate

Based on the estimates as shown in Table 3, we present the volumes of valorisation products and potential sales in this section.

Biosolids. The potential production of biosolids as pellets from septage is presented in Table 16.

Table 16 Potential production of biosolids from septage (Source: WWX, 2021)

Description	Unit	2021	2025	2030	2040
Discharge septage	[m3/y]	70,000	135,000	230,000	520,000
% solids before thickening & drying	[% solids]	2%	2%	2%	2%
solids	[tonnes/y]	1,400	2,700	4,600	10,400
% solids after drying	[% solids]	60%	60%	60%	60%
Dried sludge	[m3/y]	2,330	4,500	7,670	17,330
Effluent	[m3/y]	67,670	130,500	222,330	502,670
Sales price dried sludge	***[€/ton]***	***€ 1.50***	***€ 1.50***	***€ 1.50***	***€ 1.50***
Revenues dried sludge per year	[€/year]	€ -	€ 10,000	€ 10,000	€ 30,000

The potential production of biosolids from sludge from pit latrines is presented in Table 17.

Table 17 Potential production of biosolids from pit latrine faecal sludge (WWX, 2021)

Description	Unit	2021	2025	2030	2040
Discharge sludge	[m3/y]	17,100	94,500	207,000	168,000
% solids before drying	[% solids]	15%	15%	15%	15%
Solids	[tons/y]	2,565	14,175	31,050	25,200
% solids after drying	[% solids]	60%	60%	60%	60%
Dried sludge	[m3/y]	4,275	23,625	51,750	42,000
Effluent	[m3/y]	12,825	70,875	155,250	126,000
Sales price dried sludge	***[€/ton]***	***€ 1.50***	***€ 1.50***	***€ 1.50***	***€ 1.50***
Revenues dried sludge per year	[€/year]	€ 10,000	€ 40,000	€ 80,000	€ 60,000

Compost. The potential production of co-compost from septage is presented in Table 18.

Table 18 Potential production of compost from septage (WWX, 2021)

Description	Unit	2021	2025	2030	2040
Dried sludge	[m3/year]	2,330	4,500	7,670	17,330
Biodegradable solid waste / dried sludge	[1:1]	5	5	5	5
Biodegradable solid waste required	[m3/year]	11,650	22,500	38,350	86,650
Co-composting volume	[m3/year]	13,980	27,000	46,020	103,980
Loss during composting process	[%]	50%	50%	50%	50%
Co-compost per year	[m3/year]	6,990	13,500	23,010	51,990
Volumetric weight compost	[kg/l]	0.50	0.50	0.50	0.50
Co-compost per year	[tons/year]	3,495	6,750	11,505	25,995
Sales price co-compost	***[€/ton]***	***€ 80***	***€ 80***	***€ 80***	***€ 80***
Revenues co-compost per year	[€/year]	€ 280,000	€ 540,000	€ 920,000	€ 2,080,000

The production of co-compost from faecal sludge from pit latrines is presented in Table 19.

Table 19 Potential production of compost from pit latrine faecal sludge (WWX, 2021)

Description	Unit	2021	2025	2030	2040
Dried sludge	[m3/year]	4,275	23,625	51,750	42,000
Biogradable solid waste / dried sludge	[1:1]	5	5	5	5
Biogradable solid waste required	[m3/year]	21,375	118,125	258,750	210,000
Co-composting volume	[m3/year]	25,650	141,750	310,500	252,000
Loss during composting process	[%]	50%	50%	50%	50%
Co-compost per year	[m3/year]	12,825	70,875	155,250	126,000
Volumetric weight compost	[kg/l]	0.50	0.50	0.50	0.50
Co-compost per year	[tons/y]	6,413	35,438	77,625	63,000
Sales price co-compost	***[€/ton]***	***€ 80***	***€ 80***	***€ 80***	***€ 80***
Revenues co-compost per year	[€/year]	€ 510,000	€ 2,840,000	€ 6,210,000	€ 5,040,000

The production of vermicompost from septage is presented in Table 20.

Table 20 Potential production of vermicompost from septage (WWX, 2021)

Description	unit	2021	2025	2030	2040
Sludge per year	[tons/year]	2,330	4,500	7,670	17,330
worms eat	[kg/kg sludge]	2	2	2	2
Volume reduction	[%]	75%	75%	75%	75%
Vermicast production	[tons/year]	583	1,125	1,918	4,333
Sales price vermicast	***[€/ton]***	***€ 600***	***€ 600***	***€ 600***	***€ 600***
Revenues vermicast per year	[€/year]	€ 350,000	€ 680,000	€ 1,150,000	€ 2,600,000

The production of vermicompost from faecal sludge is presented in Table 21.

Table 21 Potential production of vermicompost from faecal sludge (WWX, 2021)

Description	unit	2021	2025	2030	2040
Sludge per year	[tons/y]	4,275	23,625	51,750	42,000
Worms eat	[kg/kg sludge	2	2	2	2
Volume reduction	[%]	75%	75%	75%	75%
Vermicast production	[tons/y]	1,069	5,906	12,938	10,500
Sales price vermicast	***[€/ton]***	***€ 600***	***€ 600***	***€ 600***	***€ 600***
Revenues vermicast per year	[€/year]	€ 640,000	€ 3,540,000	€ 7,760,000	€ 6,300,000

The valorisation of septage with BSF is presented in Table 22.

Table 22 Potential valorisation septage using BSF (WWX, 2021)

Description	Unit	2021	2025	2030	2040
Discharge septage	[m3/y]	70,000	135,000	230,000	520,000
% solids before thickening & drying	[% solids]	2%	2%	2%	2%
solids	[tons/year]	1,400	2,700	4,600	10,400
% solids after drying	[% solids]	25%	25%	25%	25%
Dried sludge	[m3/y]	5,600	10,800	18,400	41,600
Effluent	[m3/y]	64,400	124,200	211,600	478,400
Biodegradable solid waste / dried sludge	[1:1]	2	2	2	2
Biodegradable solid waste required	[m3/y]	11,200	21,600	36,800	83,200
Feed for BSF larvae	[m3/y]	16,800	32,400	55,200	124,800
BSF eat	[kg/kg sludge]	2	2	2	2
Volume reduction	[%]	95%	95%	95%	95%
BSF Larvae production	[tons/year]	840	1,620	2,760	6,240
Sales price BSF larvae	***[€/ton]***	***€ 1,200***	***€ 1,200***	***€ 1,200***	***€ 1,200***
Revenues BSF larvae per year	[€/year]	€ 1,010,000	€ 1,940,000	€ 3,310,000	€ 7,490,000

The production of BSF from faecal sludge is presented in Table 23.

Table 23 Potential production of BSF from faecal sludge (WWX, 2021)

Description	Unit	2021	2025	2030	2040
Discharge sludge	[m3/y]	17,100	94,500	207,000	168,000
% solids before thickening & drying	[% solids]	15%	15%	15%	15%
Solids	[tons/y]	2,565	14,175	31,050	25,200
% solids after drying	[% solids]	25%	25%	25%	25%
Dried sludge	[m3/y]	10,260	56,700	124,200	100,800
Effluent	[m3/y]	6,840	37,800	82,800	67,200
Biodegradable solid waste / dried sludge	[1:1]	2	2	2	2
Biodegradable solid waste required	[m3/y]	20,520	113,400	248,400	201,600
Feed for BSF larvae	[m3/y]	30,780	170,100	372,600	302,400
BSF eat	[kg/kg sludge	2	2	2	2
Volume reduction	[%]	95%	95%	95%	95%
BSF Larvae production	[tons/y]	1,540	8,510	18,630	15,120
Sales price BSF larvae	***[€/ton]***	***€ 1,200***	***€ 1,200***	***€ 1,200***	***€ 1,200***
Revenues BSF larvae per year	[€/year]	€ 1,850,000	€ 10,210,000	€ 22,360,000	€ 18,140,000

The valorisation of septage into biofuel is presented in Table 24.

Table 24 Potential valorisation septage into Biofuel (WWX, 2021)

Description	Unit	2021	2025	2030	2040
Discharge septage	[m3/y]	70,000	135,000	230,000	520,000
% solids before thickening & drying	[% solids]	2%	2%	2%	2%
solids	[tons/y]	1,400	2,700	4,600	10,400
% solids after drying	[% solids]	95%	95%	95%	95%
Biofuel	[m3/y]	1,474	2,842	4,842	10,947
Sales price bio fuel	***[€/ton]***	***€ 40***	***€ 40***	***€ 40***	***€ 40***
Revenues bio fuel per year	[€/year]	€ 60,000	€ 110,000	€ 190,000	€ 440,000
Energy per ton bio fuel	GJ/ton	18	18	18	18
Energy bio fuels	GJ/year	26,526	51,158	87,158	197,053
Conversion MJ --> kWh	GJ/year	3.60	3.60	3.60	3.60
Energy bio fuels	kWH/year	7,370,000	14,210,000	24,210,000	54,740,000

The valorisation of faecal sludge septage with BSF is presented in Table 25.

Table 25 Potential valorisation faecal sludge into biofuel (WWX, 2021)

Description	Unit	2021	2025	2030	2040
Discharge sludge	[m3/y]	17,100	94,500	207,000	168,000
% solids before thickening & drying	[% solids]	15%	15%	15%	15%
solids	[m3/y]	2,565	14,175	31,050	25,200
% solids after drying	[% solids]	95%	95%	95%	95%
Biofuel	[m3/y]	2,700	14,921	32,684	26,526
Sales price bio fuel	***[€/ton]***	***€ 40***	***€ 40***	***€ 40***	***€ 40***
Revenues bio fuel per year	[€/year]	€ 110,000	€ 600,000	€ 1,310,000	€ 1,060,000
Energy per ton bio fuel	GJ/ton	18	18	18	18
Energy bio fuels	GJ/year	48,600	268,579	588,316	477,474
Conversion MJ --> kWh	GJ/year	3.60	3.60	3.60	3.60
Energy bio fuels	kWH/year	13,500,000	74,610,000	163,420,000	132,630,000

6.11. Selection of most appropriate valorisation for Addis Ababa

We do not have enough information to prepare cost estimates on investment and operation and maintenance for the different options. However, in Table 26, we present an overview of the potential revenues as a first indicator for the selection.

Table 26 Overview potential revenues from different valorisation options (Source: WWX, 2021)

Description	Unit	2021	2025	2030	2040
Revenues dried sludge per year	[€/year]	€ 10,000	€ 50,000	€ 90,000	€ 90,000
Revenues co-compost per year	[€/year]	€ 790,000	€ 3,380,000	€ 7,130,000	€ 7,120,000
Revenues vermicast per year	[€/year]	€ 990,000	€ 4,220,000	€ 8,910,000	€ 8,900,000
Revenues BSF larvae per year	[€/year]	€ 2,860,000	€ 12,150,000	€ 25,670,000	€ 25,630,000
Revenues bio fuel per year	[€/year]	€ 280,000	€ 1,310,000	€ 2,810,000	€ 2,560,000

From this overview it can be concluded:

- BSF and vermicast are expected to have the highest income;
- Dried sludge and biofuel are expected to be not too interesting.

As BSF and vermicomposting are rather new to Addis, it is recommended to start with co-compost as a relatively easy a profitable first step. We recommend monitoring and evaluate the work of WaterAid closely.

7. Faecal Sludge Management Roadmap

The roadmaps are presented in Figure 37, Figure 38, Figure 39 and Figure 40.

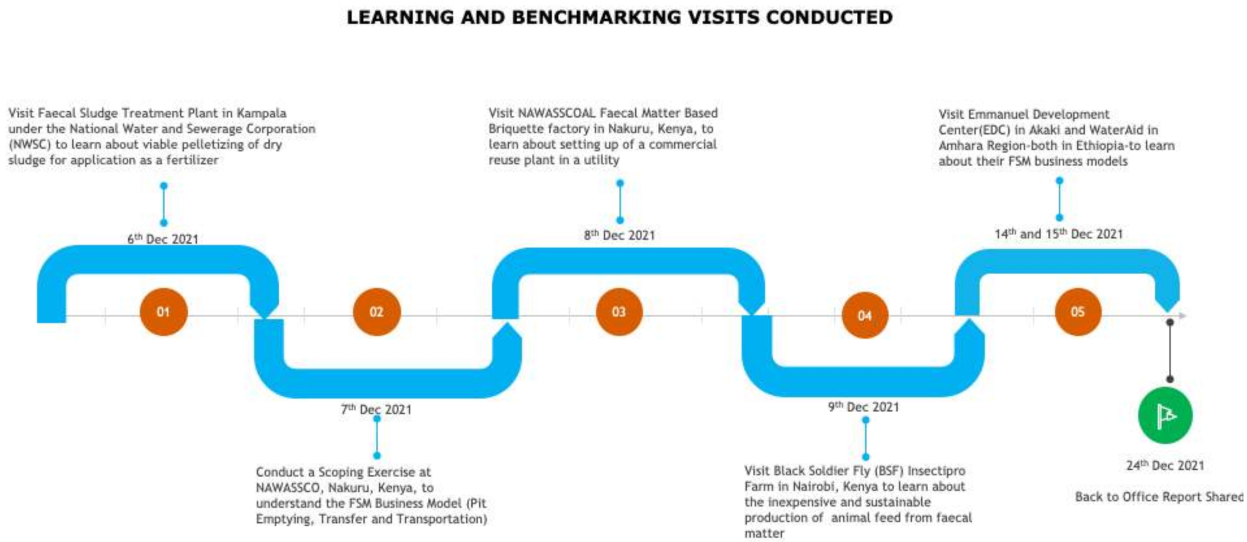


Figure 37 Learnings and visits

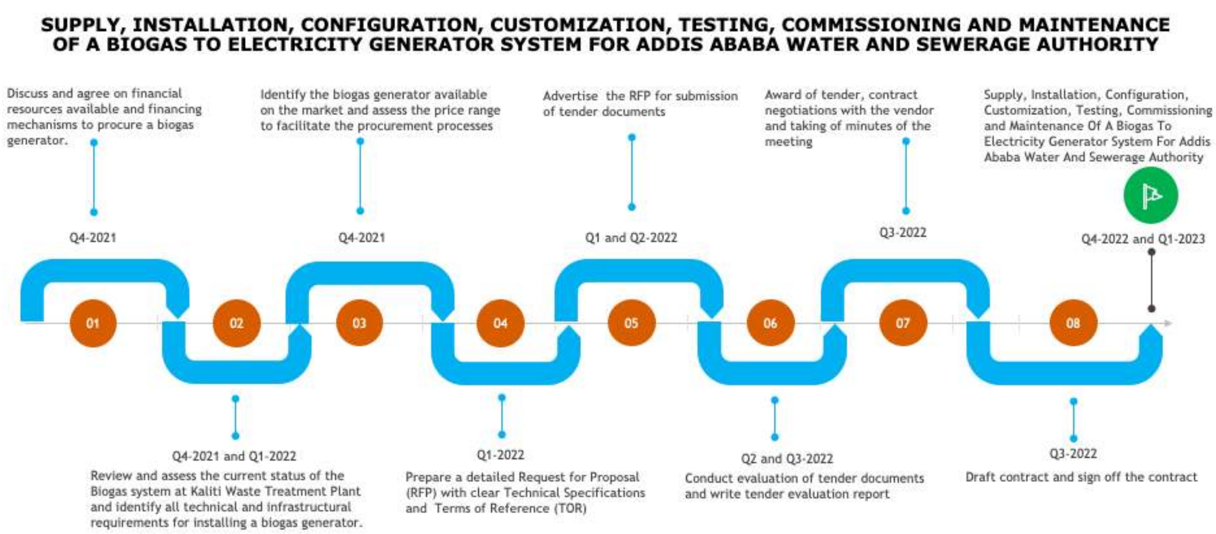


Figure 38 Biogas

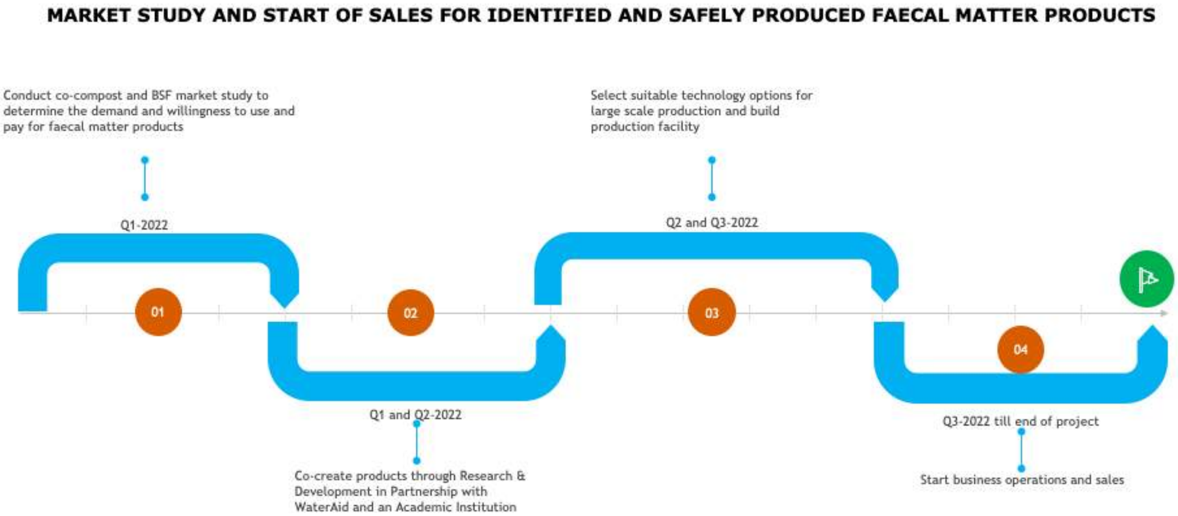


Figure 39 Market study

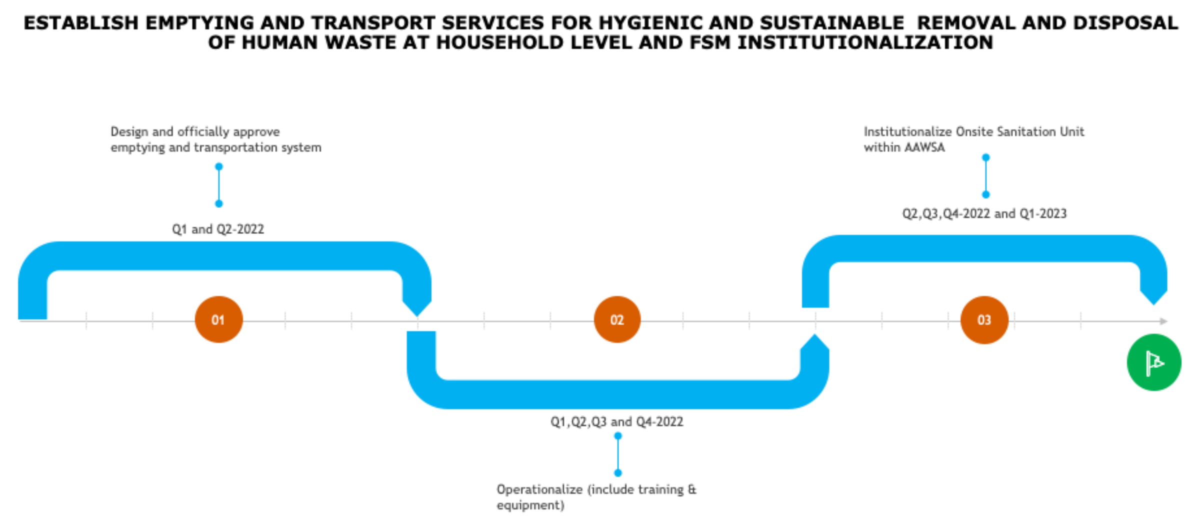


Figure 40 Emptying & transport

8. Investment plan

The investment plan is presented in Table 27 and Figure 41.

Table 27 Investment plan (Source: WWX, 2021)

Costs					
Unit prices to be confirmed	**units**	**2021**	**1st step**	**Cost**	**Revenue/year**
Improvement pit latrines through Finish Mondial	Euro/unit	€ 20	10,000	€ 200,000	
Septage treatment capacity	Euro/m3/d	€ 1,500	50	€ 80,000	€ 40,000
Faecal Sludge Treatment capacity	Euro/m3/d	€ 5,000	100	€ 500,000	€ 600,000
MDUs 3m3	Euro/unit	€ 7,500	15	€ 110,000	€ 30,000
GenSet Biogas	Euro/kW	€ 1,000	800	€ 800,000	€ 340,000
Total				**€ 1,690,000**	**€ 1,010,000**

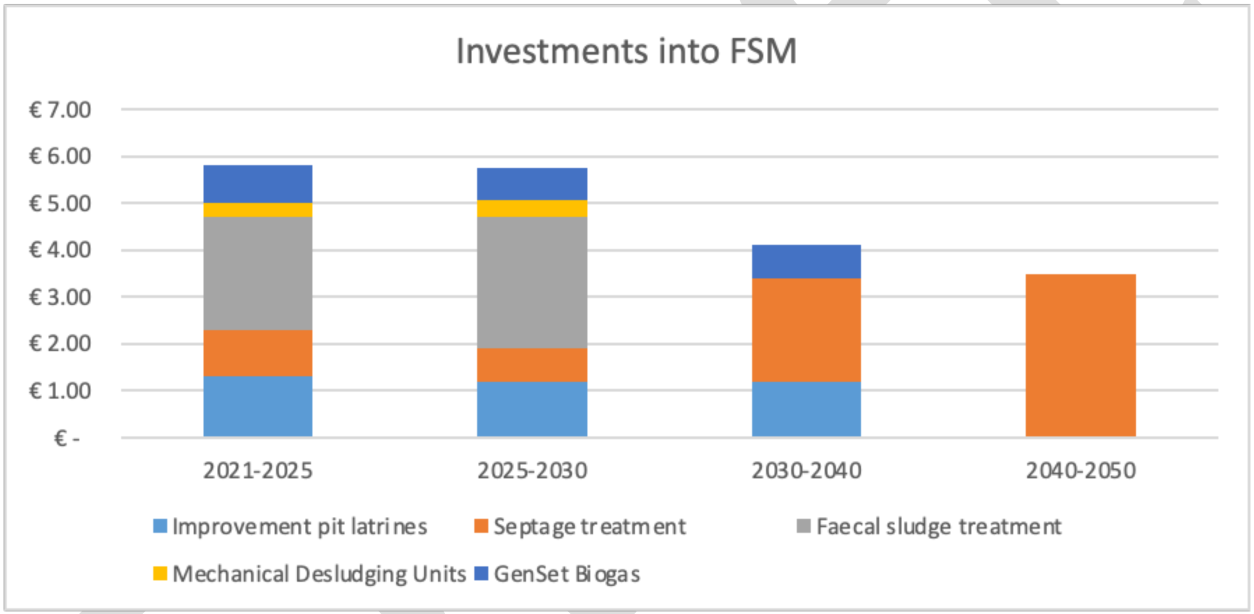


Figure 41 Investment plan (Source: WWX, 2021)

Annex 1 – Programme

Faecal Sludge Management (FSM)Needs Assessment, IWRM-4-WASH Project, Addis Ababa, Ethiopia 1st – 10th November, 2021		
Activity Item	**Responsible**	**Day**
Kick-off meeting and start desk studies	Daniel/Jan/Lawrence	1st Nov,2021
Field visit to Kaliti and Kotebe treatment plant to assess opportunities for FSM	Jan/Lawrence/AAWSA-Sewerage Superintended	2nd Nov,2021
Courtesy call to and consultation with AAWSA and WaterAid on FSM activities and understand priorities, solid waste management municipality (market waste & beautification/ landscaping)	Daniel/Jan/Lawrence/AAWSA	3rd Nov, 2021
Courtesy call One-WASH-Programme and continue desk study, minister of water (& energy including biomass/ biogas). Ministry of agriculture on crop fertilization / tree (nurseries) irrigation, aquaculture, aquaponics, poultry / fish feed, co-composting, vermicomposting, etc.)	Daniel/Jan/Lawrence	4th Nov, 2021
Field visit to peri-urban low income areas and established urban to assess sanitation facilities and condominium sewers	Daniel/Jan/Lawrence/AAWSA-Sewerage Superintended	5th Nov, 2021
Start developing FSM intervention strategies and roadmap	Jan/Lawrence	6th – 8th Nov, 2021
Presentation of FSM findings to AAWSA	Jan/Lawrence	9th Nov, 2021
Finalisation and submission of FSM report (intervention strategies and roadmap)	Jan/Lawrence	10th Nov, 2021
Elaboration report	Jan	11th Nov, 2021
Elaboration report	Jan	12th Nov, 2021

Annex 2 – Terms of Reference

Activity 4.2.1 Assess the sanitation and hygiene needs for communities living within and adjacent to the catchment

Project:
Integrated Water Resources Management for Water Sanitation and Hygiene (IWRM4WASH) - a Market-based Approach, Ethiopia.

Request for Position/Job title:
- Faecal Sludge Management Experts

Location: Addis Ababa and Oromia Region, Ethiopia

Assignment Period
- 1st November,2021 - 10th November, 2021

Requested Expertise / competence:
- Demonstrated experience in urban and rural faecal sludge management models.
- Knowledge of global best practice in urban and sanitation policy and implementation.

Context and Background:

Over the last decade, Ethiopia has achieved remarkable economic growth which aimed at improving the livelihood and wellbeing of its population. Whereas the expansion of the economy is lauded, other emerging challenges such as rural-urban migration, climate change, deforestation, gender equality, air pollution, global health, globalisation, and geopolitics among others are slowly stifling progress towards achieving sustainable developing goals (SDGs) which has resulted to increased pressure to deliver essential services.

Ethiopia has made significant progress in water and sanitation over the last two decades. According to WHO/UNICEF Joint Monitoring Programme 2014 report, the country has improved water supply by 57% (97% in urban areas and 42% in rural areas), thus achieving the Millennium Development Goal (MDG) 7 target 7C. Although the sanitation target has not yet been achieved, there has been tremendous progress during the past decade in improving sanitation and ending open defecation. The progress has been largely due to the establishment of a government-led WASH coordination mechanism (ONE WASH programme) involving Ministry of Water, Health, Education and Finance and Economic Development, as well as development partners.

With the improved access to sanitation in Ethiopia, many regional cities exist limited formal services for collection, transportation, disposal, or treatment of the resulting faecal sludge. Few instances of resource recovery through processing faecal sludge exist. The service delivery gaps within and between the stages of the sanitation service chain become more apparent as urban sanitation access increases. Failure to ensure strong links throughout the faecal sludge management (FSM) service chain results in untreated faecal sludge (FS) contaminating the environment, with serious implications for human health.

General Project information:

The IWRM4WASH project is a five-year Integrated Water Resources Management project to be implemented in the catchment areas of Legedadi, Akaki, Dire and Gerfesa, through funding by the Embassy of the kingdom of the Netherlands (EKN). It will be implemented by Vitens Evides International (VEI, Lead partner) in partnership with SNV Netherlands Development Organization (Implementing Partner) on the one hand, and Addis Ababa Water and Sewerage Agency (AAWSA, Beneficiary Partner) and Oromia Water Bureau (OWB, Beneficiary Partner) on the other. In addition, the project will work closely with associated water utilities of Akaki, Burayu, Gelan, Salulta and Sendafa. The development objective of the IWRM4WASH project is to improve water resource protection in Addis Ababa's water catchment by up scaling and anchoring IWRM approaches with special focus on increased water and sanitation supply benefiting approximately 1.3 million people; and strengthening market-based approaches to stimulate self-sufficiency and sustainability of water and sanitation services in line with the provisions of the Sustainable Development Goals (SDGs).

Specific Assignments of mission:

1. Design of an operational mechanism for faecal sludge emptying, collection, transportation, and handling for re-use;
2. Undertake a quick scan of guidelines on safe faecal waste treatment and handling for safe re-use;
3. Draft guidelines on safe faecal sludge handling and re-use.

Activities:

- Meet one on one or remotely with institutions involved in FSM, such as Addis Ababa Water and Sewerage Agency (AAWSA), Oromia Water Bureau (OWB), Private Sector, Ministry of Health (MoH), Ministry of the Environment (MoE), Department of Water Resources, WASH Development partners etc;
- Visit the wastewater treatment plant, private operators (truck operators);
- Generate a basic draft faecal waste flow diagram with available data and identify what additional data and stakeholder buy in would need to be done to conduct a complete catchment-wide inclusive sanitation delivery assessment;
- Generate an FSM organization chart delineating roles (including roles around the collection and treatment of FSM;
- Identify gaps and overlaps but also needed cross-institutional linkages;
- Facilitate discussions regarding the institutional framework with the sanitation board, sanitation and hygiene working group and other key stakeholders

Deliverables:

- Faecal sludge management study Report;
- Draft manual for Operational and sustainable system for Faecal Sludge collection and transportation and disposal;
- A summary report for secondary collection and transport system.
- A proposal and intervention strategy for FSM

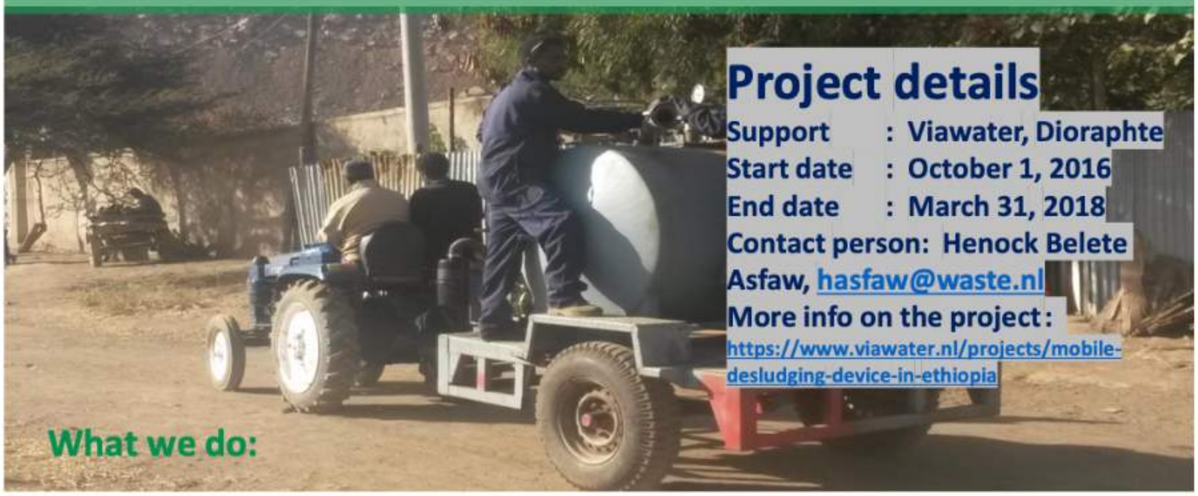
Conditions:

- The activities will take place in/with all the participating water utilities;
- The short-term experts will be working with the Technical Managers and be supported by a member of the IWRM4WASH team.

Annex 3 – Fact sheet MDU WASTE / ViaWater Ethiopia

Piloting and Production of Mini Desludging *Unit*

The overall objective of this project is to develop locally made (with mostly local materials) mini desludging device in Ethiopia and develop the business around it.



Project details

Support : Viawater, Dioraphte
Start date : October 1, 2016
End date : March 31, 2018
Contact person: Henock Belete Asfaw, hasfaw@waste.nl
More info on the project:
https://www.viawater.nl/projects/mobile-desludging-device-in-ethiopia

What we do:

The number of latrines and septic tanks that are being constructed in developing countries are significantly increasing year by year. Despite of this growth, little attention is given to develop services to empty these pits. Vacuum trucks deliver services which are not affordable for latrine pit owners, and moreover, are not adequate to access the pits in densely populated areas. As a consequence, pits are often closed when they are full. In addition; vacuum trucks are rarely providing the right service, as they can hardly enter into narrow streets and are not fit to deal with high density sludge and waste products.

During the ESP project (www.emergencysanitationproject.org) a concept was developed to overcome the said challenges. We are now in demonstration phase to produce a locally manufactured small desludging device that is necessary to empty small pits which contain 'difficult' sludge and are hard to access. Currently we are developing a 1000 litre vacuum tank size desludging device. It's business viability will be examined during the testing period.

How we do it: approach

The project has 5 phases:

Phase 1: Basic research: In the first phase the concept of the project was designed

Phase 2: Proof of concept: In the second phase the concept was assessed and a pre-feasibility of the market was carried out.

Phase 3: Early stage technology development: In the third phase, he actual prototypes will be built, tested and demonstrated on difficult sludge (household pit latrines and public toilets)

Phase 4: Product development: In the fourth phase, the focus was on further analysis of the market for the desludging device (MDU) and production of the desludging device. WASTE and B4A (Aqua for All) will work closely with Yassin Industries.

Phase 5: Product marketing: In this phase the product(s) will be manufactured and the first machines will be sold to potential customers.

Sustainability:

In order to develop sustainable and viable business out of such device, the equipment will be built locally by local materials and local people so that maintenance and repair measures can be taken on spot in short period time.

Specification of a Mobile Desludging Unit

Vacuum Pump	Engine	Fluidizer/high pressure pump	Vacuum tank	Fresh water tank	Other parts
- Capacity 2500 lit/min - 2000 rpm - Max vacuum - -0.65bar - Safety valve for vacuum pressure of 0.7bar	- 4200 CC - 4 stroke - 9.1hp	- Model Bosch - 120 bar - Length of high pressure hose 5 meters - Drive Electric - Water yield 350 liters / hour	- Capacity 950 litres (net 850 litres) - Anty dust painted - Inlet at top and outlet at bottom - 2 inch vacuum inlet - Safety valve for over pressure	- Capacity 85 litres - Antirust painted - Inlet at top and outlet at bottom	- 2 wheel cart (to carry the vacuum tank, pump, engine water tank and fludizer) - 4 wheel tractor (for transport)

About WASTE: The mission of WASTE is to 'turn waste into prosperity'. For over 30 years and in more than 20 countries, our advisers empower people to build sustainable waste management systems. Creating healthy environments, jobs and healthy & happy people. Read more on www.waste.nl.