Faecal Sludge Management in low-income settlements –Lessons learnt from Dar es Salaam

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Figure 1: The FSM "service chain" for the specific context of Dar es Salaam

Introduction

BORDA's approach is to establish integrated and complementary solutions with a focus on the facilitation of essential public services in the water, wastewater, solid waste and urban development sectors. Within the UKAID financed 'Human Development Innovation Fund' (HDIF) project entitled "Decentralised Wastewater Treatment Systems (DEWATS) For Dar es Salaam (Dar)", BORDA Tanzania and its partner Ifakara Health Institute (IHI) replicated an innovative approach for faecal sludge management (FSM) in unplanned urban areas characterised by low-income, high population density, and with no sewerage connections to the centralised network. The project aimed to develop sustainable cost recovery models for decentralised FSM that includes (a) decentralised treatment plants for faecal sludge; (b) establishing local businesses to provide hygienic and professional pit emptying services and transportation of faecal sludge, (c) develop the enabling environment for scaling-up this sustainable approach in Dar es Salaam. Between 2016 and 2020 two Faecal Sludge Treatment Plants (FSTPs) were constructed and a sanitation service provision team established. It provided the opportunity to trial and optimise the operation and maintenance of the systems, before being handed over to the Public Utility, Dar es Salaam Water and Sanitation Authority (DAWASA).

The Innovation Opportunity

The project responded to the current crisis of inadequate provision of sanitation services, in Dar es Salaam, where the vast majority of residents live in unplanned, densely populated settlements, and where unsafe, informal and illegal practices for sanitation service provision are common. As the level of urbanisation increases, so does the need for innovative and inclusive sanitation. Conventional (centralised) systems have consistently failed in these challenging urban contexts as they require resources beyond the available capacities. Additionally, conventional systems are difficult to implement in cities experiencing such rapid unplanned urban expansion, as the infrastructure coverage simply cannot keep up with the speed of growth.

A promising innovative approach, which enables step-wise implementation and adaptation as the city expands, is decentralised FSM, which was piloted and demonstrated within this project. Decentralised treatment technologies were piloted in this project, after proving to be an effective solution in former projects. This innovative approach for treatment was tested in combination with pioneering tools and equipment for emptying and transportation of faecal sludge – in order to optimise and improve the entire sanitation chain from waste generation to the point of safe reuse or disposal.

The Innovation

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

The Innovation: Emptying & Transportation

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

Figure 2: Service providers discharging sludge into Mburahati Faecal Sludge Treatment Plant

The Innovation: Treatment

The small-scale faecal sludge treatment plants (FSTPs) (5-10m^3 per day) with minimal operational requirement (no electrical energy, chemicals, nor complex mechanical equipment) treat faecal sludge to a standard, which is safe for infiltration into the ground, or for reuse with subsurface irrigation systems.

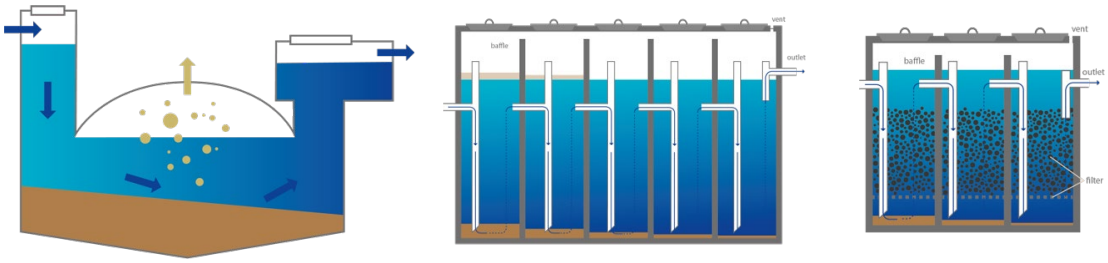


Figure 3: FSTP treatment modules

Additionally FSTPs can be constructed and operated using locally available resources and local artisans, resulting in robustness of the system, and low capital and operational costs. The systems are constructed underground on small pieces of land, meaning that they can be integrated into densely populated urban communities – reducing the negative impact on the surrounding environment (e.g. in comparison to large, open wastewater stabilisation ponds).

The Innovation: Reuse or final disposal

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

The Innovation: Cost recovery model

The cost recovery model [1] for FSM consists of pit emptying/transportation services and management of the FSTP by a small private sector entity. Service fees are collected at the household level, for pit emptying and transportation services conducted by the operators employed by the private entity. The fees help to recover operational expenses, by paying for operator salaries, and maintenance of the equipment and vehicles. In the long-term arrangements, the FSTPs are owned and maintained by the public utility.

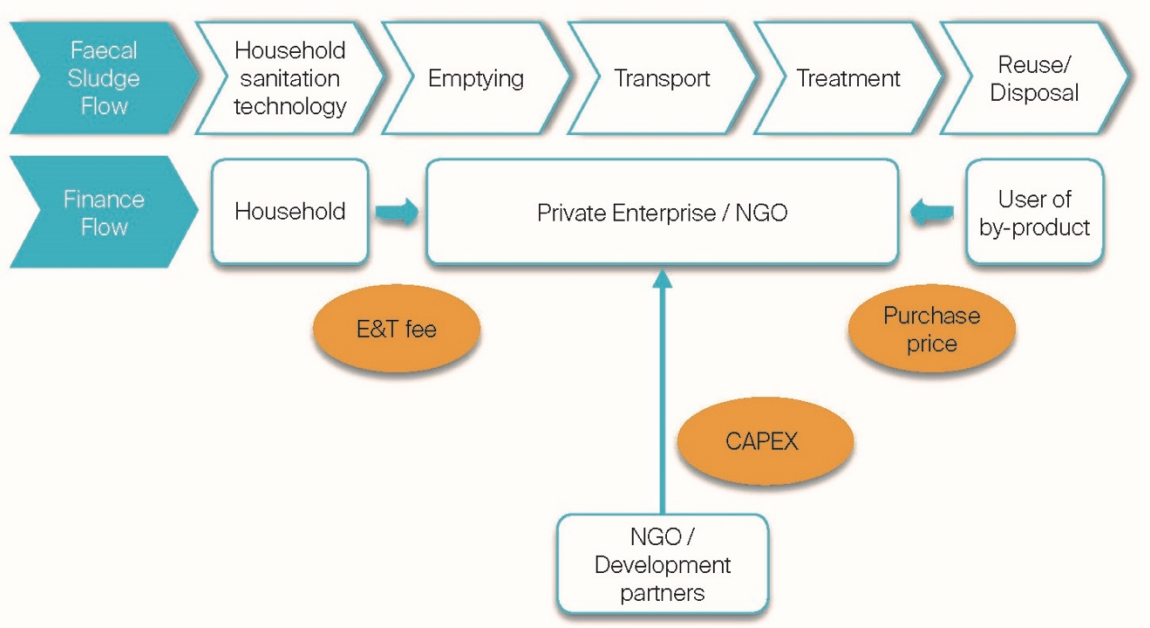


Figure 4: FSM cost recovery model

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

[1] The term “cost recovery model” is used, instead of “business model” as the experiences prove that the business is not profitable. However, it’s still possible to reduce the operational costs and minimise the need for subsidies, through optimised cost recovery.

acceptance of the system. After handover of the system, the BORDA (NGO) is substituted by the public water and sanitation utility and other responsible government agencies (e.g. Ministry of Water).

"Now that we have the treatment system in our community, the environment is cleaner and there is no more wastewater in the streets. And because of the good new services, my toilet is very clean, no cockroaches, diseases have reduced in my family. The new service responds quickly and provides the service on time, and it's not expensive - compared to private truck that is expensive and do not come on time"

- Community representative from Wailes sub-ward, Miburani

The Innovation: Partnerships with stakeholders

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

Some of the stakeholders that have been engaged include, national and local government authorities, municipalities of Ubungo, Temeke and Kinondoni, Kigamboni and Ilala the Dar es salaam Water and Sanitation authority (DAWASA), academia, private service-providers, financial institutions operators and artisans, civil society organisations and other development partners. These stakeholders provided continuous support, particularly relating to the social and environmental impact assessment, and the provision of public-owned land for construction of the FSTPs

Figure 5: A young female supervisor was hired to oversee the service provider team

Gender equality was a high priority throughout this project, with women and men equally involved in all project activities, including project coordination, decision making and implementation. Local women were also engaged during construction of the FSTPs and a female supervisor was hired to oversee the service provider teams. Women were identified as influential champions in awareness creation and behaviour change on FSM, and as such they were trained specifically on topics such as solid waste and menstrual hygiene management (e.g. proper disposal of solid waste, including used menstrual hygiene products A likely outcome of this initiative is that less solid waste is thrown into pits and septic tanks, therefore reducing the negative impacts of solid waste entering the FSTPs.

Figure 6: Local women were engaged during FSTP construction

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

The Innovation: Community engagement

In addition to stakeholder engagement, the project success was strengthened through public awareness creation and marketing campaigns. Awareness creation was conducted in the form of community general assemblies, focus group discussions, workshops, training, community sanitation exhibitions, poster installations and a sanitation bonanza.

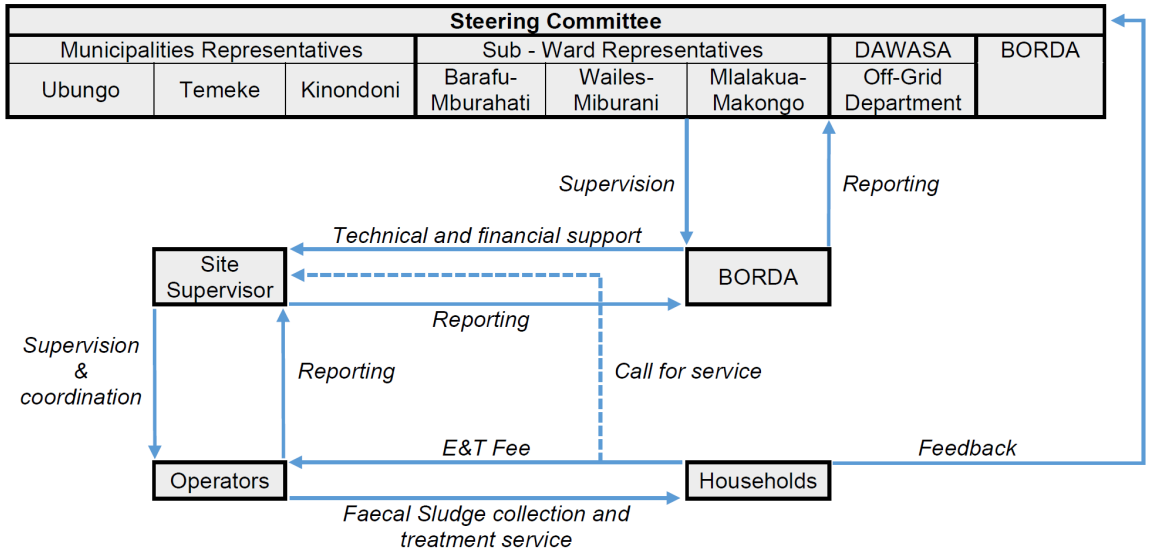


Figure 7: Setup of the FSM Steering Committee

The Innovation: Education and awareness was provided which enabled the implementation, operation/maintenance and handover if the FSM system. The topics included:

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

Figure 8: Training conducted with local women on FSM, solid waste and menstrual hygiene management

A public marketing campaign was undertaken to promote sanitation behaviour change and the FSM services. This campaign was in the form of radio announcements; posters installed at local government offices and other public places; loud-speaker messages announced while driving through the communities; and door-to-door visits and distribution of brochures.

Challenges and breakthroughs

Challenges and breakthroughs: Site selection and land acquisition

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

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

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

It took more than 1.5 years to obtain land instead of initially forecasted time of 6 months. This was after visiting 45 sites, evaluating 17 shortlisted sites, in order to select and obtain two sites, which were provide as in-kind contribution from the Municipalities: one in Mburahati ward, Ubungo Municipality (adjacent to the Barafu sub-ward office, 450m²) and one in Miburani ward, Temeke Municipality (on the land of the Wailes/Likwati public school, 850m²). These two sites then required construction approval from the Municipal Council, which was only possible after community acceptance of the project and the Municipality officially changed the land use. The success in finally obtaining land was due to the commitment of the LGAs and the partnerships with Barafu sub-ward, Wailes sub-ward and, the primary schools of Wailes/Likwati, who supported this project to be implemented within their jurisdictions.

Figure 9: FSTPs at Mburahati (left) and Miburani (right)

Challenges and breakthroughs: Financial and institutional arrangements to operationalise the FSTPs"

The initial business concept for FSM services did not take off as planned; hence, it was challenging to operationalise the FSTPs after construction and to offer FSM services to the communities. The original concept was to empower local entrepreneurs to purchase their own start-up equipment (with their own capital, or by taking out a bank loan). The payback period for the initial outlay was estimated to be approximately 9 months (without a bank loan) or 21 months (with bank loan).

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

- Few private enterprises were willing or able to invest in the start-up equipment as there were no reliable data available to demonstrate the feasibility of the business concept, and the finance models were mainly based on assumptions.

- Financial institutions were either unwilling to provide loans, or interest rates were so high that the loans were prohibitive for prospective entrepreneurs.
- Very few service-providers had sufficient experience in FSM.
- Experience from solid waste shows challenges of collecting service fees from households with many unwilling to pay the fees.

Eventually BORDA publicly tendered and selected the most promising service providers

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

"Small-scale decentralised FSM services are customised to the needs and challenges of communities in unplanned, low-income settlements of Dar es Salaam; providing safe and professional solutions to households that would otherwise have no access to adequate pit emptying services."

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

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

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

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

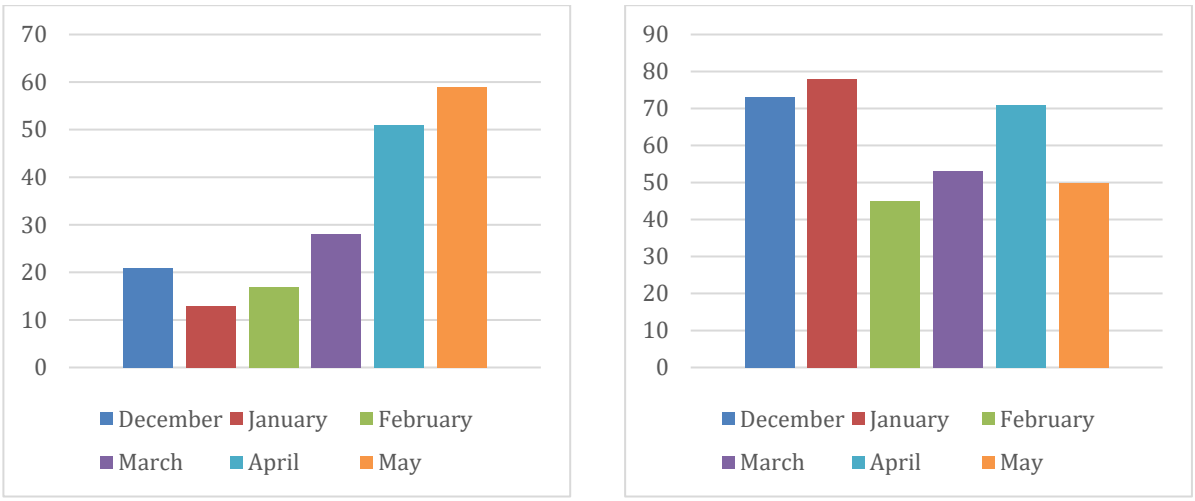
With this new information that the FSTPs would eventually be managed by the public utility, the focus shifted from empowering local entrepreneurs, to instead empowering DAWASA –

particularly as DAWASA also intends to scale-up FSM at a city-wide level. In order to ensure a smooth transition, supervision and guided “handover” efforts were required

The steering committee therefore agreed that BORDA should establish and closely monitor one ‘centralised’ team of service providers for a fixed period of one year to manage three decentralised treatment plants, and provide pit-emptying services to residents in the project areas. The main objectives were to:

- support the operators,
- field-test different tools, technologies and equipment to provide innovative service provision models (e.g. ‘eVAC’, mud pump, trash pump, in different combinations with the motorised tricycle and small vacuum truck).
- collect data on financial, environmental and social performance of the systems in order to optimise the service provision, and reduce the subsidies.

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



From April 2019 to May 2020 (14 months) a total of 1,810m³ of faecal sludge were collected in 623 trips and treated at the three FSTPs. This served the needs of approximately 15,500 people. Clients who received the service were interviewed through phone calls. 85% of the clients who were interviewed responded positive to quick availability and accessibility of the service to their sites.

Figure 10: Total Number of Trips by Motorised Tricycle (Left) and Vacuum Truck (Right), between December 2019 – May 2020

Although the process to implementing innovative faecal sludge management (FSM) in Dar es Salaam was not straightforward, it ultimately proved to be a success story, as this project demonstrated that decentralised FSM can be successfully implemented in challenging urban settings. If the site selection criteria can be fulfilled, then FSTPs can be implemented. Likewise, this project demonstrates the potential of integrating underground FSTPs on small sites (e.g.

directly bordering a Ward-Office, a central football pitch, a public school, households, small shops and restaurants) that fulfil the site selection criteria, allowing inclusive provision of FSM services in any other low-income urban settlement in Tanzania and other high density urban centres in Africa.

Challenges and breakthroughs: Strengthened enabling environment
The lessons learnt throughout this project were regularly shared with high level stakeholders within the local and national sanitation sector. Recommendations relating to the enabling environment were provided upon request, specifically focussing on aspects of institutional arrangements, legal & regulatory framework, government support, socio-cultural acceptance, financial arrangements and skills & capacity.

As a result, several major sector developments occurred during the implementation period of the project. Stakeholders who were involved in these processes were informed by the "DEWATS for DAR" project and appreciated the tangible experience it provided. These achievements include:

- Review of the Maji Design Manual
- Guidelines for on-site sanitation and FSM
- National Water Policy (NaWaPo)
- Development of an Off-Grid department within DAWASA
- The inauguration of a project for scaling-up decentralised FSM in Dar es Salaam (10 small to medium size FSTPs in the first phase of the project)

Learning

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

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

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

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

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

1. Natural, Environmental and Physical Factors
    a. Land area (including space for disposal of effluent and sludge): should be minimum 450m2 for a 10m3 FSTP
    b. Accessibility: vehicle access to the site should be provided for construction, operation and maintenance
    c. Distance to the closest household: ideally the site should be located at least 50m from the nearest household
    d. Soil Characteristics & Conditions: Free soil (unconsolidated)
    e. Vulnerability to Natural Hazards (Flooding, Site Erosion)
    f. Ground water table: at least 2m deep
2. Legal, Institutional and Administrative Factors
    a. Proper Land Use: land-use zones allow for the construction of treatment facility in this location
    b. Ease of ownership: guarantee to be able to acquire land, either through purchase or in-kind contribution
    c. Settlement structure
    d. Future Expansion Plan: No risk to vehicular access due to future urbanisation or development
3. Socio-Economic and Cultural Factors
    a. Site Potential: close proximity to customers and demand (economy of scale)
    b. Support of the community: do they accept the intervention in their area
    c. Economic situation of the community: is the community willing and able to pay for sanitation services

Learning: Technology

FSTP: The DEWATS approach for faecal sludge treatment proves to be a good solution due to its low operational requirements and low-to-no nuisance emission. Nevertheless, the correct level of decentralisation needs to be determined for each context.

The small-scale treatment plants can be very well integrated in urban areas, but if they are too small to accept vacuum trucks (smaller than 10m³/day), a continuous inflow of faecal sludge and cost recovery are difficult to achieve. On the other hand, if they get too big (depending on the availability of land), the reuse of the treated liquid fraction of the faecal sludge is challenging. Subsurface irrigation and infiltration require much area. It was observed that constructing subsurface irrigation schemes in public areas is challenging due to interference with other activities, which can even lead to damaging of the system.

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

Table 1: Treatment performance of FSTPs in Ubungo, Temeke and Kinondoni

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

Pit emptying and sludge transportation technology: Within this project a variety of pit emptying and faecal sludge transportation (E&T) technologies were tested. A summary of the learnings (based on data collected during this project) is provided in the table below.

Table 2: Summary of the E&T learnings

E&T Technology	Facts	Strengths	Weaknesses
Transportation technology			
Small Vacuum truck (3.7m3 capacity)	• Investment cost: • App. 25,000USD (good condition, second hand) • Volume per trip: max (3.7m³) • Trips per day: 3 • Time per trip: 2h	• High carriage capacity • Fast emptying possible, for all types of sludge (in the context of Dar es Salaam) • Physically easy to operate	• High CAPEX and OPEX • Import can be challenging • Only used in accessible areas. • Requires skilled operators
Motorised Tricycle (1m3 capacity)	• Investment cost: • App. 2,000USD • Volume per trip: max. 1m³ • Trips per day: 2 • Time per trip: 1h30min	• Low CAPEX and OPEX • Locally available • Can reach even less-accessible areas, compared to vacuum trucks	• Low carriage capacity • Cannot directly access all areas, but can be used in combination with sealable containers which can be manually carried to those inaccessible houses
Pit emptying technology			
Mud / Water Pump	Investment cost: App. 400USD	• Very low CAPEX and OPEX • Locally available • Very mobile	• Can only pump very watery septage. • Requires frequent maintenance and full replacement after app. 1 year of operation. • Can only be applied in arrears where the

E&T Technology	Facts	Strengths	Weaknesses
			motorised tricycle can access.
Trash Pump	Investment cost: App. 1,000USD	• Very powerful pump, and thus fast emptying (1m³ in 2min) • Can be manually carried into areas not accessible via vehicles • Locally available • Can pump septage with particles up to 15mm size.	• High investment costs • Not appropriate for thick sludge • Can only be applied in arrears where the motorised tricycle can access
'eVAC'	Investment cost: App. 4,000USD	• Very powerful vacuum system; can pump thick sludge (1m³ in 1 hour, including the handling of the drums) • Very mobile system; can access almost all areas. • Very low operational costs.	• Is not yet locally available but could be manufactured locally. • Importing from South Africa is possible. • The tested version is powered by electricity (challenging during power cuts), but a version with a petrol engine is available. • Carrying the drums from the pit to the tricycle is tough physical work.

Learning: Cost recovery model

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

For example, in the case of Mlalakuwa, the local entrepreneur – even with financial and technical support from BORDA – was unable to provide regular pit-emptying services, mainly due to an initial lack of willingness to pay from the clients. Similarly, in Mburahati, due to the slow pay-back period and high interest rates on micro-finance loans for start-up equipment, the service provider quickly lost interest and prioritised higher-paying clients such as hotels and businesses.

In general, it was observed that the cost of providing the improved service was higher than the willingness to pay by the households. The fees collected from the households could cover only 50% of the O&M costs. This is a hindering factor for the private sector to invest in the FSM

services, but these lessons will now guide DAWASA to consider the necessary financing mechanisms as they plan to take over the FSTPs and the FSM service provision. It was concluded that the provision of FSM services which protect the environment and the public health require cross subsidies to sustainably finance the operational costs of emptying, transportation and treatment. This could be in the form of a sanitation levy on the water bills.

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