CASE STUDY 5

Anaerobic respiration for faecal sludge treatment and reuse

Lusaka,
Zambia

SNV

UTS Institute for Sustainable Futures

Background

Formal emptying and treatment of sludge collected from on-site sanitation facilities in Lusaka Zambia was established between 2012 and 2014 through the construction of two Faecal Sludge Treatment Plants (FSTPs) and the consequential development of pit emptying teams in two peri-urban compounds in the city, namely Kanyama in the South and Chazanga in the North. The FSTPs are owned by the Lusaka Water and Sanitation Company (LWSC) and managed by the Kanyama and Chazanga Water Trusts, which are community-based organisations (CBOs).

Treatment selection and purpose

The main objectives of the Kanyama and Chazanga FSTPs are sludge stabilisation through anaerobic digestion and (sludge) resource recovery: in the form of biogas as a fuel, and stabilised sludge as a soil conditioner. The FSTPs were financed by the Water and Sanitation for the Urban Poor (WSUP) through a Stone Family Foundation grant. The Kanyama FSTP was designed by the Bremen Overseas Research and Development Association (BORDA) in partnership with the Water and Sanitation Association of Zambia (WASAZA), with WSUP providing ongoing technical support. The Chazanga FSTP was a modification of the Kanyama FSTP approach. According to BORDA Zambia, the anaerobic system approach for the FSTP design was chosen for its high sludge stabilisation efficiency and low energy requirements for operations and maintenance (O&M). Obtaining biogas from the primary treatment process was a secondary motivation. Initially, the managers considered supplying biogas to nearby households as an alternative to fuel, but biogas is now reserved for use on-site.

> *The essence of the pilot project was to stabilise and dry the sludge. Natural gravity flow, low energy requirements, biogas for cooking were also part of the motivation.*
>
> **PROJECT ENGINEER, BORDA ZAMBIA**

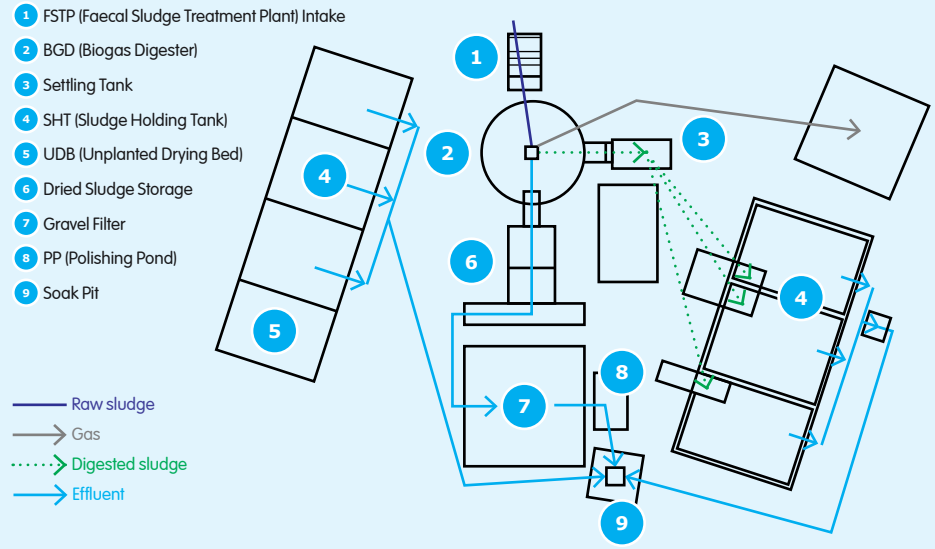
Chazanga biogas digester in construction

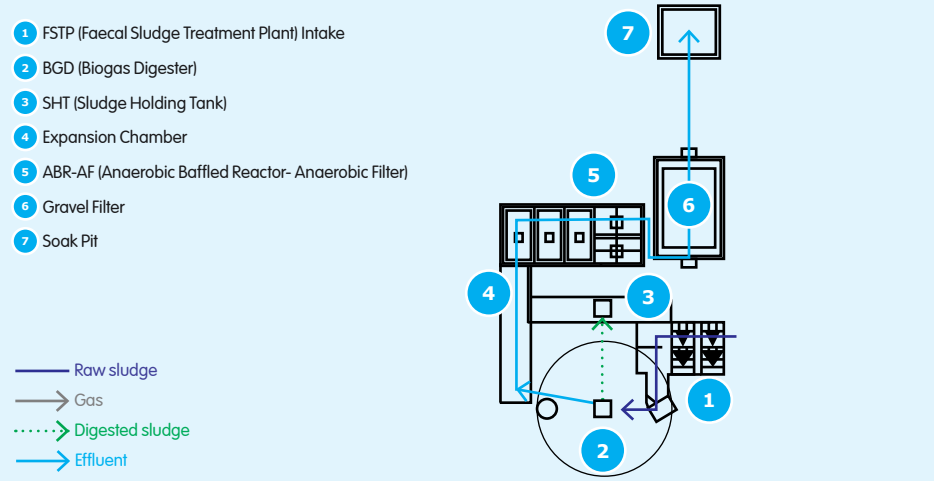
Kanyama FSTP worker emptying sludge

Description of the system

The Kanyama and Chazanga FSTPs have similar process flows, with key differences in the secondary treatment phase only. The FSTPs are designed solely for manually emptied pit latrine sludge. Sludge is transported to the facilities in 60L barrels and carried in open pickup trucks. At the FSTPs, the sludge in barrels is discharged into a series of chambers with the first two chambers having sloping floors and inclined bar screens for solid waste separation. The solid waste captured by the bar screens is placed on separate drying racks in preparation for its transportation to a landfill. The second chamber leads to a sand trap in which sand and grit from the sludge is retained to prevent it from flowing into the primary treatment unit, which is a fixed-dome Biogas Digester (BGD). Each facility has a fixed-dome biogas digester, with the Kanyama FSTP having a 58 m^3 dome and the Chazanga a 50 m^3 dome. The main purpose of the BGDs is to stabilise and digest the fresh and raw sludge. The sludge is homogenised inside the unit due to the turbulence created by changes in pressures during biogas production and consumption. The stabilised sludge then flows naturally by gravity and gas pressure into sludge holding tanks from which the sludge is pumped into tertiary stabilisation units before being sold for reuse. The incoming sludge and increasing gas pressure push the liquid from the BGD into the secondary treatment stage.

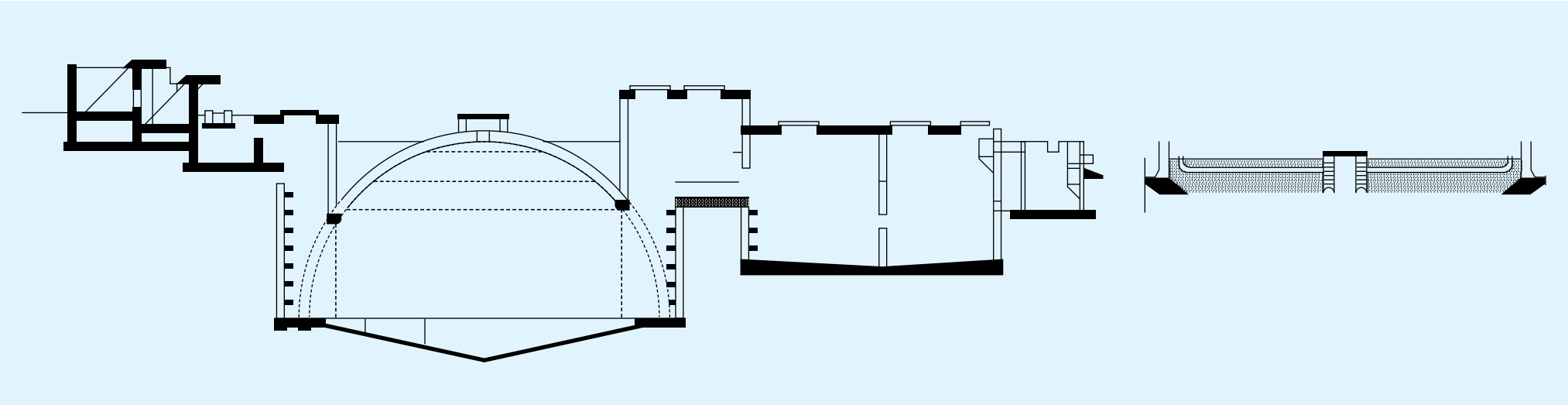
Figure 1. Presentation of Chazanga FSTP layout plan and flow diagram (top)[2] and Kanyama FSTP layout plan and flow diagram (bottom)[3] adapted by SNV





[1] A. Simwambi, S. Hibler, B. Pietruschka and P. Hawkins, 'Approaches to Faecal Sludge Management in Peri-Urban Areas: A Case Study in the City of Lusaka', in P. Hawkins and I. Blackett, eds., *FSM Innovation Overview and Analysis, Implementing FSM Services: Emerging Examples of Success*, Seattle, Bill & Melinda Gates Foundation, 2017.
[2] M. Klinger, A. Gueye, A. Manandhar Sherpa and L. Strande, 'Scoping Study: Faecal Sludge Treatment Plants in South-Asia and sub-Saharan Africa', *eFSTP Project Report*, Zurich, eawag, 2010, p.31, https://dqo52087pnd5x.cloudfront.net/posters/docs/gatesopenres-191067.pdf (accessed 9 November 2020).
[3] eawag, *eFSTP Phase I - Scoping study, Chazanga, Kanyama and Manchini (Lusaka)*, Zurich, eawag, 2019, p. 3.

Figure 2. Chazanga FSTP section plan with intake, BGD, settling tank, expansion chamber, and gravel filter[4] adapted by SNV



Secondary treatment of the liquid effluent from the BGDs differs in the Chazanga and Kanyama facilities. In Chazanga, two settling chambers and a rectangular expansion chamber separate the liquids and solids from the BGD. The liquid is pushed out of the treatment unit through a pipe towards the gravel filter, which is the next treatment component. The solids (sludge) remain to settle in the settling chambers as the liquid passes through the unit. The chambers are emptied at least twice a year, and the sludge is transferred into sludge drying beds or a sludge holding tank. In Kanyama, the BGD is connected to an expansion chamber and an anaerobic baffled reactor consisting of three chambers and one anaerobic filter with two chambers (ABR-AF). Anaerobic degradation of the effluent occurs in the ABR-AF, with the liquid effluent flowing to the gravel filter via an overflow pipe. Solid matter that settles in the three baffled chambers needs to be emptied regularly, with the frequency depending on incoming effluent characteristics. The removed sludge is transferred to off-site drying beds.

While both facilities utilise unplanted sludge drying beds (both covered and uncovered) for solid-liquid separation of the settled stabilised sludge, the drying beds are located onsite at the Chazanga facility, and off-site at the Kanyama facility as there is not enough land available for the latter. Sludge delivered at the Kanyama FSTP is stabilised in the biogas digester or holding tank (at another site) before being pumped out by a vacuum truck through the desludging tank and taken to the off-site drying beds. At the Chazanga FSTP, the BGD stabilised sludge is pumped out of the desludging tank using a trash pump and dried in on-site sludge drying beds.[1] The Chazanga FSTP has six operational sludge drying beds whose leachates drain through a sand and gravel filter media in layers. The leachate from the drying beds flows into a soak pit from which it drains into the environment. After the dewatering of the sludge, it is manually removed by the plant operators and stacked in the dried sludge storage space. The dried sludge is sold for reuse as a soil conditioner. In the case of Kanyama, sludge is transported to the Manchinchi Wastewater Treatment site for co-treatment or it is placed for direct drying on beds as there is fear of cross contamination of nearby boreholes at the Kanyama site.

Both facilities use a gravel filter and soak pit for final treatment of the liquid effluent. In Chazanga, the effluent then moves from the gravel filter to a polishing pond (shallow open tank) that stores the liquid before it goes to the soak pit. Through exposure to UV light, further treatment can occur. The treated effluent is used to dilute incoming faecal sludge to clean equipment and to water the facility gardens. The final stage of treatment is the soak pit, which is a covered, porous-walled chamber that is designed to discharge treated effluent into the surrounding soil.

[4] eawag, eFSTP Phase I – Scoping study, Chazanga, Kanyama and Manchinchi (Lusaka), 2019, p.3.

Roofed sludge drying beds at Kanyama FSTP

Lined but not roofed drying beds at Kanyama FSTP

Sorting and drying solid waste at Kanyama FSTP

Table 1. Capacity and operating costs of the Chazanga and Kanyama FSTPs

	Sludge drying beds
Design capacity	4 m^3 of sludge/day
Operating capacity	5-7 m^3 of sludge/day
Operating costs CAPEX (capital expenditure) OPEX (operational expenditure)	**Chazanga FSTP** CAPEX: US$ 166,500 OPEX: US$ 490-1,080/month (salaries, electricity, O&M) Revenue: US$ 366-975/month (emptying services and sale of biosolids) **Kanyama FSTP** CAPEX: US$ 70,000 OPEX: US$ 1,090-1,440/month (salaries, electricity, O&M) Revenue: US$ 1,058-1,480/month (emptying services and sale of biosolids)

Regulatory environment and compliance

National standards for faecal sludge effluent are in development due to the newness of the approach, with water pollution control regulations currently used for environmental compliance purposes. Several quality standards (limits) for effluent and wastewater are mentioned in the government regulation, 'Third Schedule Regulations 5(2) of The Water Pollution Control (Effluent and Waste Water)'.[5] These include for BOD to not exceed 50 mg/L, Total Dissolved Solids to not exceed 3000 mg/L, and Total Suspended Solids to not exceed 100 mg/L. Results of laboratory testing from the Chazanga and Kanyama facilities were not available.

[5] *The Environmental Protection and Pollution Control Act (1990)* Ministry of Legal Affairs, Government of the Republic of Zambia, http://www.parliament.gov.zm/sites/default/files/documents/acts/Environmental%20Protection%20and%20Pollution%20Control%20Act.pdf (accessed 5 November 2020).

Operation and maintenance: realities, challenges, and opportunities

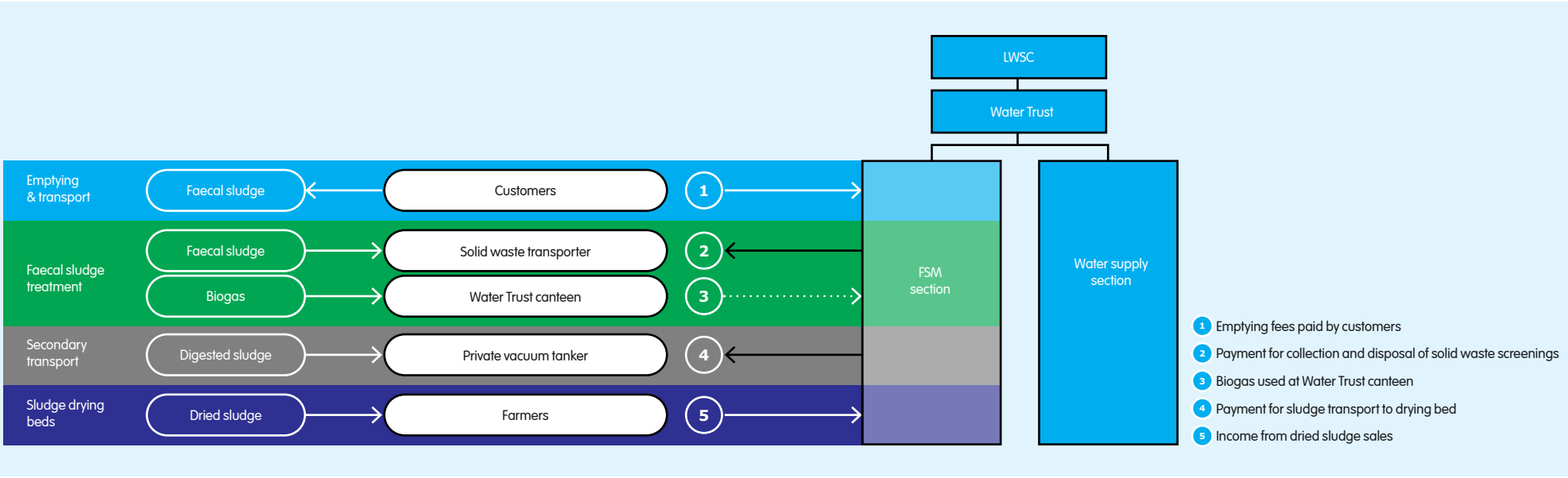
Realities of running the treatment plant

Governance, management, and revenue arrangements

The LWSC owns the FSTP facilities and is responsible for major capital investments, repairs, and providing expert input to the Water Trusts operators. The Kanyama and Chazanga Water Trusts are community-based enterprises owned by local residents, with community oversight by Ward Development Committees and the Lusaka City Council Area Councillor sitting as Water Trust Board Chair. These enterprises are responsible for the day-to-day operations of faecal sludge management services in their respective communities.[6] The Water Trusts employ community-based pit emptiers who are paid on a commission basis. The emptiers are paid 60% of the total FSM revenue and 40% is retained to pay maintenance costs such as management of screened solid waste, transportation of sludge to the drying beds, disinfectants, and purchase of safety equipment. Figure 3 outlines the FSM management by the Kanyama Water Trust, including an overview of revenue flows.

Biogas produced from the Kanyama BGD

Figure 3. Kanyama Water Trust FSM management,[7] adapted by SNV



[6] A. Simwambi, S. Hibler, B. Pietruschka and P. Hawkins, 'Approaches to Faecal Sludge Management in Peri-Urban Areas: A Case Study in the City of Lusaka', 2017.
[7] *eFSTP* Phase 1, 2019, p. 3.

Chazanga FSTP grit separation at influent discharge point

Washing trough for cleaning barrels at the Kanyama FSTP

Construction considerations

During construction and rehabilitation of the Chazanga and Kanyama FSTPs key considerations included ensuring sufficient personnel were available, water proofing of the biogas digester, addressing concerns about flooding, and responding to community concerns. Identified pit emptiers who would later be working for the Water Trust partook in construction works so that they would gain familiarity with the FSTP technology. An external bricklayer, familiar with biogas digester construction, was hired to supervise and guide the local pit emptiers and bricklayers. Engineers from BORDA and WASAZA were also involved in training and supervising the construction process.

To ensure that the biogas digester was waterproof, it was lined with 6mm-thick dam lining materials and reinforced with steel and mortar to reduce the chances of groundwater contamination. For the Kanyama FSTP, flooding was one of the major considerations in facility design and construction. The compound is seated on a dolomite rock formation and prone to frequent flooding, which meant that the FSTP needed to be raised a little off the ground to avoid water ingress. Being a rocky subsurface, a lot of blasting was required. Community engagement processes before and during construction were facilitated to address any public objection risks.

> *Informal pit emptiers were engaged as construction workers so as to start inculcating aspects of system ownership in them.*
>
> **PROJECT ENGINEER, BORDA ZAMBIA**

Staffing arrangements and OHS measures

At both the Kanyama and Chazanga FSTPs, staff are equipped with the necessary occupational health and safety (OHS) training and support measures. Eight semi-skilled staff are employed at each facility and are involved in pit latrine emptying as well as operation of the FSTPs.

All staff are provided with the necessary personal protective equipment. They have received on-the-job training in the following areas: OHS, Standard Operational Procedures (administrative and technical), O&M procedures for the treatment units, and emptying and desludging techniques. OHS measures that have been implemented at the facilities include construction of a ramp to the discharge point so that staff can easily roll the barrels full of faecal sludge for disposal rather than lifting them, and handwashing facilities for workers and provision to clean the barrels in a hygienic manner, while recovering the used water back into the system. All staff undergo periodic medical check-ups, are are provided with oral cholera, tetanus, and hepatitis B vaccines.

> *Community engagement processes included sensitisations and exposure visits to facilities using biogas digester technology.*
>
> **PROJECT ENGINEER, BORDA ZAMBIA**

Challenges of construction, and operation and maintenance

Clogging due to high sand and solid waste content

According to the system operators, the Chazanga and Kanyama FSTPs become blocked two to three times a year due to the high sand, sediment, and solid waste content from pit latrines and lack of regular maintenance. High solid waste content of the sludge (up to 20% solid waste) leads to blockages in the perforated distribution pipes of the BGD, the secondary settler chambers, and the sand traps. As the received sludge is very thick and the facilities have limited water access and water pressure, they encounter difficulties in diluting the sludge to achieve the required consistency for a good flow. This challenge resulted in the facilities being shut down for an average of three weeks (2-3 times per year), forcing the pit emptiers to undertake manual emptying using buckets. Extra funds from the Water Trusts are required to cover the pit emptiers' salaries while they undertake the work.

During normal operations, the solid waste is screened out from the sludge. But when the facilities need to be shut down 2-3 times per year, solid waste is dried and then periodically moved to the municipal landfill by a registered waste transporter at a cost of US$ 40/tonne.[8]

> *There were times when the system was overfed with too much sludge. The accumulation of sand from pits is another challenge, which makes the system fill faster and reduce the retention time.*
>
> **FSM BUSINESS DEVELOPMENT LEAD, LUSAKA WATER SUPPLY AND SANITATION COMPANY**

Inside the Chazanga biogas digester

Overloaded and non-operational drying beds

Currently, the Chazanga FSTP drying beds are overloaded with sludge, and the drying beds used for the Kanyama FSTP are non-operational. In Chazanga, capacity of the six drying beds is not sufficient for all the settled sludge processed at the facility. As a result, a temporary sludge receiving chamber was built in order to store the excess sludge, particularly when the BGD and settling chambers are being desludged. At the Kanyama facility, there are no drying beds onsite, and the 12 beds that were being used about three kilometres away have been decommissioned due to their close proximity to boreholes. Currently, all sludge collected by the Kanyama FSTP is taken to the decommissioned Manchinchi Wastewater Treatment Plant for storage in their sludge holding tanks. The construction of two new sludge drying beds has been proposed at a new site within the Kanyama settlement, about one kilometre from the Kanyama FSTP. Construction is planned for 2021.

> *Both facilities experience operational challenges with the sludge drying beds.*
>
> **FSM AND DESIGN ENGINEER, WSUP**

[8] A. Simwambi, S. Hibler, B. Pietruschka and P. Hawkins, 2017.

Kanyama FSTP decommissioned sludge drying beds

Dried sludge for sale

Pricing of services constrained by customers' willingness to pay and market competition

The pricing of FSM services offered by the Chanzanga and Kanyama facilities is based on estimated ongoing O&M costs but is constrained by customers' willingness to pay and the need to compete with informal service providers. The pricing model requires customers to pay US$ 34 for 12 sixty-litre barrels, US$ 48 for 24 barrels, and US$ 68 for 32 barrels.[9] This pricing model has not been sufficient to cover all O&M costs as not enough customers took up this service. The pricing model changed in 2020 with support from the Lusaka Sanitation Programme, which intends to increase uptake through price reduction and provision of incentives for private-sector vacuum operators to desludge pit latrines. This has resulted in a lower price for households of US$ 7/m^3. What is unclear is for how long this lower price can be sustained.

Opportunities for reuse

To generate revenue through resource recovery, it was planned for the dried sludge to be sold as a soil conditioner and for biogas to be sold to nearby households. At present, the processed and dried sludge is packaged and sold to landscapers as a soil conditioner. Within the initial design of the FSTP, the biogas produced by the BGD was intended to be piped for sale to nearby households at a value equivalent to that of charcoal. However, this failed as these houses were predominantly occupied by tenants who could not get consent from their landlords for the gas connections.[10] In addition, the price of the gas was higher than that of coal and electricity. The cost to connect only a few houses was not financially viable. The gas is therefore used by the Water Trusts themselves, for the workers' canteen in Kanyama and by the caretaker living at the Chazanga FSTP site. Gas production is approximately 12.5 m^3/d but is greatly dependent on the amount of sludge fed into the biodigester each day. The gas is mainly used for cooking, and the estimated consumption is about 4-6 m^3/d, with the excess gas burnt in the open air.

[9] A. Simwambi, S. Hibler, B. Pietruschka and P. Hawkins, 2017.
[10] A. Simwambi, S. Hibler, B. Pietruschka and P. Hawkins, 2017.

Informed choice considerations	Biogas digesters for treatment and reuse in Lusaka, Zambia (Lusaka Water and Sanitation Company)
Operating & design capacity	Design capacity = 4 m^3/day of sludge Operating capacity = 5-7 m^3/day of sludge
Operating costs	**Chazanga FSTP** CAPEX: US$ 115,000 (initial costs) + US$ 11,500 (additional works, e.g., extra drying beds) = US$ 166,500 OPEX: US$ 490-1,080/month OPEX (salaries, electricity, O&M) Revenue: US$ 366-975/month (emptying services and sale of biosolids) **Kanyama FSTP** CAPEX: US$ 125,000 OPEX: US$ 1,090-1,440/month (salaries, electricity, O&M) Revenue: US$ 1,058-1,480/month (emptying services and sale of biosolids)
Energy requirements	Natural system, no energy requirements
Input characteristics	Solid waste fraction of sludge up to 20%
Land requirement	970 m^2 for Kanyama without drying beds, and Chazanga with drying beds on 1,400 m^2 plot
Skills and human resources requirements	Eight semi-skilled staff are employed at each facility (Kanyama and Chazanga) and are involved in pit latrine emptying as well as operation of the FSTPs
Technology/material local availability	Materials and manufacturing all locally available and managed

References

Eawag, eFSTP Phase I – *Scoping study, Chazanga, Kanyama and Manchinchi (Lusaka)*, Zurich, eawag, 2019.

Klinger, M., Gueye, A., Manandhar Sherpa, A. and Strande, L., 'Scoping Study: Faecal Sludge Treatment Plants in South-Asia and sub-Saharan Africa', *eFSTP Project Report*, Zurich, eawag, 2010, https://dqo52087pnd5x.cloudfront.net/posters/docs/gatesopenres-191067.pdf (accessed 9 November 2020).

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This paper is a chapter in a publication of nine case studies presenting real-life faecal sludge and wastewater treatment practices. The stories were narrated by plant owners, operators, SNV staff, and partners in Indonesia, Bangladesh, Kenya, Zambia, Malaysia, India, South Africa, and Benin. The full publication was reviewed by Antoinette Kome and Rajeev Munankami, and available for download at: https://snv.org/cms/sites/default/files/explore/download/2021-treatment-technologies-in-practice-snvisf-uts-full-publication.pdf.

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