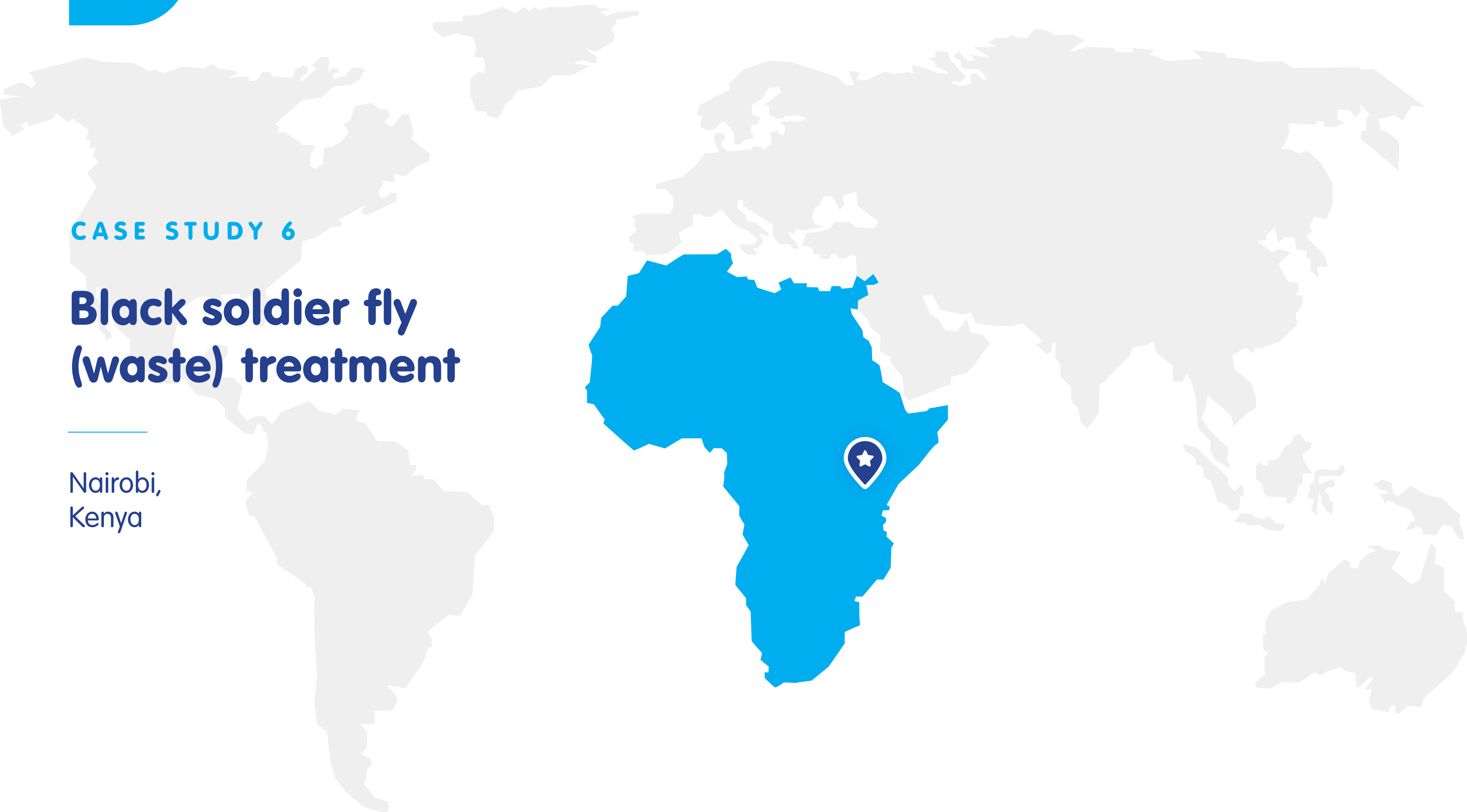
CASE STUDY 6

Black soldier fly (waste) treatment

Nairobi,
Kenya



SNV

UTS Institute for Sustainable Futures

Background

Treatment selection and purpose

Sanergy has been using Black Soldier Fly (BSF) systems to treat and upcycle organic waste into agricultural products and biomass briquettes. As a social enterprise, Sanergy was created in 2011 in response to the inadequate access to safe sanitation and waste management services experienced by Nairobi residents living in slums. Sanergy also saw an opportunity to develop agricultural inputs, such as insect-based protein for animal feed and organic fertiliser. Sanergy uses a full value chain approach, and the BSF technology was initially trialled in Kenya through a partnership with the Bill & Melinda Gates Foundation in 2013.

> *In Nairobi, 66% of all faecal waste generated ends up untreated back in the ecosystem, polluting the environment and harming public health. As Sanergy envisions to effect a systems change, we have developed an urban pit waste management service that aims to capture and contain manually emptied pit latrine waste in a formalised way.*
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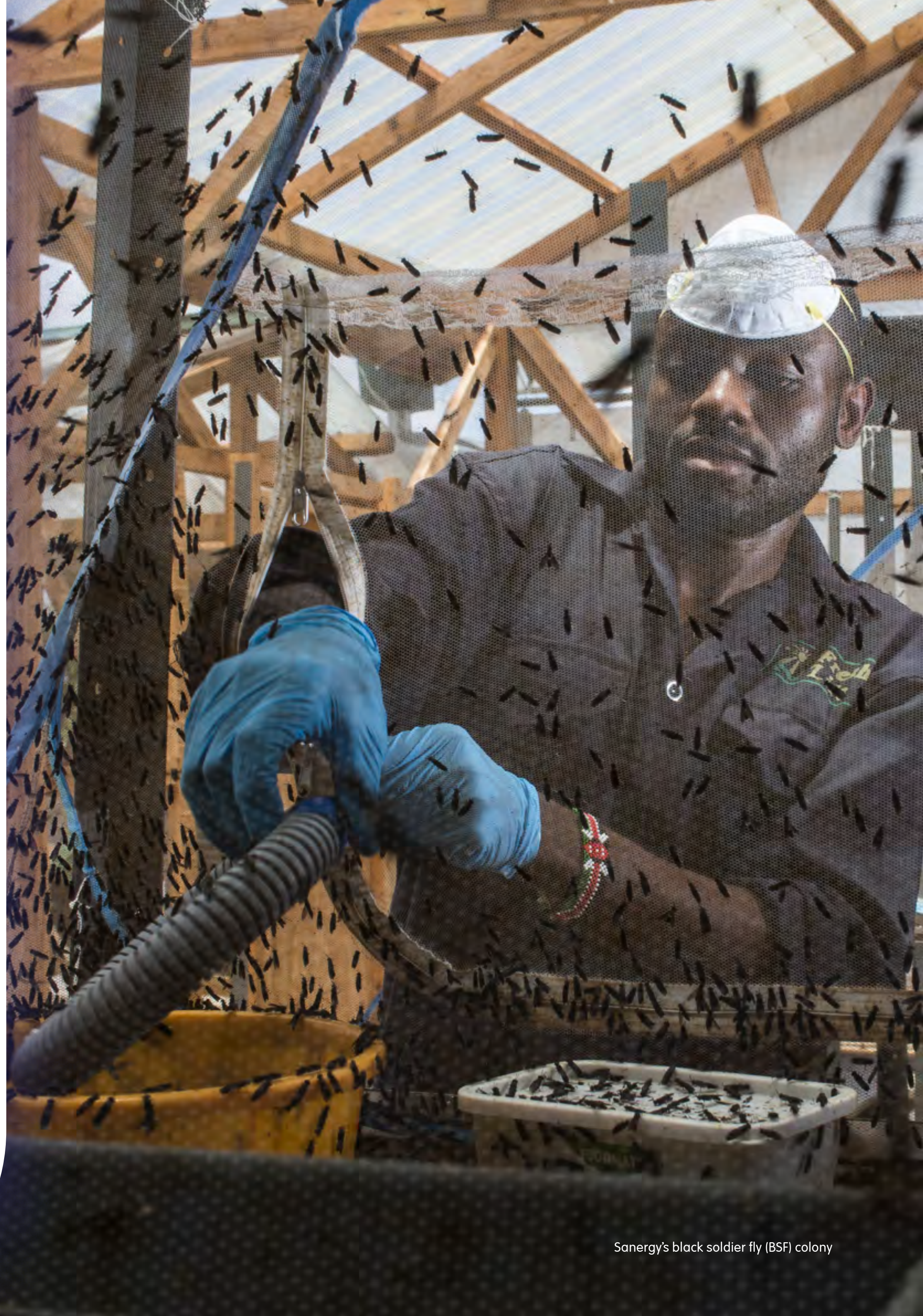


Sanergy's black soldier fly (BSF) colony

Fresh Life container based, urine-diverting toilet

Description of the system

Sanergy utilises BSF larvae and thermophilic composting to treat and upcycle faecal sludge, agricultural waste, and market and kitchen food waste. Faecal sludge is contained in Fresh Life Toilets (a container-based system used for the storage of human waste) in Nairobi. These toilets are designed to reduce the moisture content of the sludge by separating urine and faeces. As of December 2019, Sanergy had installed a total of 3,247 Fresh Life Toilets in 11 informal settlements, serving over 80,000 urban residents. The containers, which hold the sludge, are double sealed and collected by operators with handcarts that transport the sludge to a decentralised collection point. Filled-up containers are replaced with clean empty containers in the Fresh Life Toilets. The containers are collected from the decentralised collection point and transported by vehicle to a transfer station, where the sludge is consolidated in large barrels and transported by truck to the treatment plant.

The BSF larvae break down organic material and return nutrients to the soil. The BSF system harnesses this process to convert organic materials – such as manure, agricultural waste, food waste, and human sludge – into usable by-products. In BSF processing facilities such as Sanergy's, the BSF larvae feed on decomposing organic material, and the larvae grow from a few millimetres to around 2.5 cm in 14 to 16 days, while reducing the wet weight of the waste by up to 80%.[1] The BSF larvae are 'harvested prior to the prepupal stage using a mechanical agitator to separate them from organic wastes.' Due to the high protein (approximately 35%) and fat (approximately 30%) content of the larvae, they can be used as animal feed. The frass residue (excrement from insect larvae) can be used as a soil conditioner but requires further treatment.[2] At Sanergy, the frass residue is mixed with carbon sources from plant waste in thermophilic composting windrows to produce organic fertiliser. Temperature, aeration, and moisture content are systematically measured to ensure a high-quality compost. Fuel briquettes are also produced from the frass residue through pyrolysis for use at the treatment facility. This helps reduce fossil fuel consumption and operating costs.

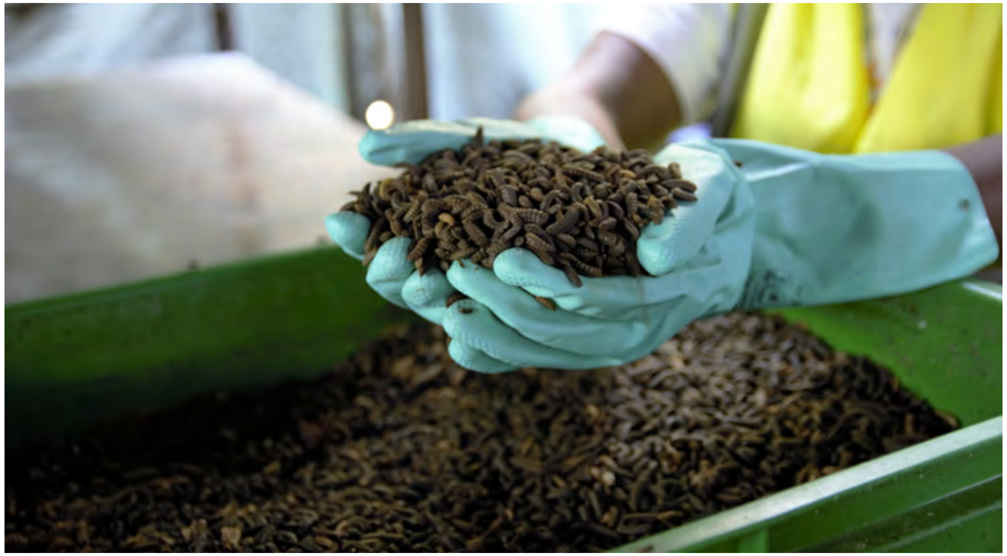
The Fresh Life Toilets ensure containment and separation of faeces and urine. Sanergy is also working with agricultural pack houses, markets, and restaurants to separate organic food waste from inorganic waste, plastics, and metals. The food waste is placed in dedicated containers that are collected and transported by Sanergy to other waste management and recycling companies. Sanergy is also exploring options to use pit latrine sludge by dewatering it first. While urine is currently safely disposed of, Sanergy is exploring options to reuse it.

Table 1. Capacity and operating costs of BSF treatment plant

	Conventional treatment plant
Design capacity	7t (current) and 200t (planned) of faecal sludge and organic waste/day
Operating capacity	7t (current) and 200t (planned) of faecal sludge and organic waste/day
Costs	Capital expenditure, CAPEX = US$ 7 million

[1] B.M.A. Dortmans, S. Diener, B.M. Verstappen and C. Zurbrügg, *Black soldier fly biowaste processing: a step-by-step guide*, Dübendorf: eawag, 2017, https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/BSF/BSF_Biowaste_Processing_HR.pdf (accessed 8 April 2020).
[2] K. Tayler, *Faecal sludge and septage treatment: a guide for low- and middle-income countries*, Rugby, Practical Action Publishing, 2018, https://www.pseau.org/outils/ouvrages/practical_action_faecal_sludge_and_septage_treatment_a_guide_for_low_and_middle_income_countries_2018.pdf (accessed 25 April 2020), p. 332.

Emptiers removing sludge from Fresh Life toilets


BSF larvae ready for harvesting

Regulatory environment and compliance

Sanergy contracts third parties to test their end products to ensure compliance with international standards such as ISO 16649 and ISO 6579. Laboratories in operation at the treatment facility conduct testing of the sludge at various points in the process to ensure the BSF treatment removes pathogens from the end products including the fertiliser and animal feed, based on testing of E.coli. Independent testing by credible laboratories such as NAS-SERVAIR is conducted for comparison and to ensure the end products are free of pathogens.

Operation and maintenance: realities, challenges, and opportunities

Realities of running the treatment plant

Staffing and training

Sanergy has over 250 employees involved in waste collection, waste processing, distribution of agricultural inputs, strengthening the enabling environment (government regulation and policy), and research and development (R&D) activities. Regular training of all employees is conducted, particularly for emptying and treatment operators. Operators meet at forums for peer learning. Additionally, Sanergy has recently helped one group of 22 manual pit emptiers to become a formally registered community-based organisation (CBO) that is able to legally operate. Sanergy provides a waste transfer station for safe disposal of pit waste and helps emptiers to build professionalism in their work, through the use of personal protective gear, and by enhancing hygiene standards for themselves and their work.

Seed funding and financial sustainability

Sanergy financed the plant's initial set-up through seed funding and grants. Sanergy's growth has been supported by philanthropic partners and impact investors. To build the model's financial sustainability, Sanergy earns revenue from its for-profit arm, including through the sale of organic fertilisers and insect-based animal feed.

Challenges of operation and maintenance

Environmental conditions for BSF system

A key challenge faced by Sanergy was in establishing the correct environmental conditions to support BSF reproduction and growth cycles. Providing the right food source and climatic conditions to best mimic the natural habitat of the BSF for maximum output required a number of trials by the Sanergy R&D team. Regular monitoring of BSF reproduction and growth is required to ensure a reliable and steady supply of larvae to process waste. BSF reproduction and growth are sensitive to a number of environmental conditions including temperature, humidity, light, depth of organic waste, and ventilation.[3] To improve the food source of the BSF larvae, food and agricultural waste were mixed in with the faecal sludge. These measures assisted in scaling up the reproduction of BSFs and producing protein-rich insect-based animal feed.

Need for a strong enabling environment

Towards the beginning of production, Sanergy faced challenges in relation to land tenure for the toilet facilities in informal settlements, as well as in government policies that limited the manufacture and sale of waste-derived products. Policy changes were needed, and this was achieved by working in partnership with government, municipalities and other sanitation stakeholders. An enabling environment was created that supported the review and amendment of policies related to the treatment and reuse of waste to manufacture valuable products, and endorsement of container-based sanitation systems.

> *To realise our vision of providing safe sanitation to everyone and implement our circular economy approach to solve urban waste management challenges, Sanergy recognised that working with the government from the onset is very critical.*
>
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Lessons learnt

Investment and ongoing research required

Upfront investment and ongoing research are required to successfully treat and convert waste into agricultural inputs and alternative fuel products. Sanergy's recycling factory is the largest in East Africa. It has been adapted to use technologies developed in-house by Sanergy's team of engineers. All these have involved significant investment. In addition, investing in continuous research to improve product quality and standard operating procedures has been viewed as essential to improve the efficiency of the process and maximise revenue from the sale of high-quality products. Sanergy has partnered with various research organisations to support the continuous improvement process, and to promote the ongoing capacity building of the Sanergy staff.

Importance of understanding community needs

Sanergy has learnt that while marketing campaigns have a role to play in product and service promotion, they are particularly important for encouraging sanitation uptake and behaviour change. Personalised and targeted problem-led conversations with the different community members which address their needs have been found to be an effective way to ensure buy-in to Sanergy services and products. By directly addressing existing challenges, such as the agricultural and energy challenges faced by farmers and communities, buy-in for the products has been established.

Sanergy has also learnt that engaging with customers frequently and listening to what they value is central to providing a product or service that they actually use. In the case of the Fresh Life Toilet, Sanergy's team of engineers has continued to improve the toilet's design to incorporate customer feedback to solve any problems with toilet use. For example, version 3.0 of the Fresh Life Toilet, launched in 2015, includes a child- and woman-friendly squat plate, an interior with an easy-to-clean tile floor, and a squat-support to help people with disabilities to use the toilet.

> *In order to operate successfully, we have established an open and collaborative relationship with the communities where we work.*
>
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[3] K, Tayler, *Faecal sludge and septage treatment*, 2018.

Informed choice considerations

Black soldier fly treatment as reuse in Nairobi, Kenya (Sanergy)

Operating & design capacity	Design capacity = 7t (current) and 200t (planned) of waste per day Operating capacity = 7t (current) and 200t (planned) of waste per day
Operating costs	Capital expenditure, CAPEX = US$ 7 million
Energy requirements	Solar energy utilised: 350 MWh/month Mains (grid) electricity utilised: 87 MWh/month
Input characteristics	E. coli: $1.5x10^5$ to $2.0x10^5$ cfu/g*
Output characteristics	E.coli: <10 cfu/g
Land requirement	The area required for BSF processes is approximately 500-750 m^2 per tonne of dry solids processed per day with an additional 60 m^2 per tonne required for a waste receiving area and to accommodate a laboratory, office and storage space, and employee facilities[4]
Skills & human resources requirements	250 staff, ranging from semi-skilled (emptiers) to skilled (engineers, researchers with tertiary qualifications)
Technology/material (local) availability	Materials and manufacturing all locally available and managed, with some technologies internationally imported

*cfu - colony forming units i.e. number of bacteria/fungi

[4] B.M.A. Dortmans, S. Diener, B.M. Verstappen and C. Zurbrügg, *Black soldier fly biowaste processing*, 2017.

References

Dortmans, B.M.A., Diener, S., Verstappen, B.M. and Zurbrügg, C., *Black soldier fly biowaste processing: a step-by-step guide*, Dübendorf: eawag, 2017, https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/BSF/BSF_Biowaste_Processing_HR.pdf (accessed 8 April 2020).

Tayler, K., *Faecal sludge and septage treatment: a guide for low- and middle-income countries*, Rugby, Practical Action Publishing, 2018, https://www.pseau.org/outils/ouvrages/practical_action_faecal_sludge_and_septage_treatment_a_guide_for_low_and_middle_income_countries_2018.pdf (accessed 25 April 2020).

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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