WaterAid Faecal Sludge Management guide

May 2022

WaterAid/Sam Vox

WaterAid

Contents

▲ Cover image:
Gulper Operator for the Newanga Usafishaji Mazingira Group (NUMAGRO). Temeke, Dar Es Salaam, Tanzania. March 2021

About this guide

What is this document and who is it for?

This guide is a reference document intended for WaterAid staff to help create better sanitation programmes. It provides the basis for a series of internal training sessions on Faecal Sludge Management (FSM), a crucial way to help achieve safely managed sanitation for everyone, everywhere.

This is not a manual, nor does it provide a single way to approach FSM for every situation. There is already a wealth of existing resources on FSM, and you can find examples of these at the end. This guide does not replace them; rather, it offers a subjective selection of approaches, principles, tools, technologies and projects that we believe are important for WaterAid.

We hope that it will also be useful beyond WaterAid, especially our partners, as well as other sanitation professionals.

How to use this guide?

This guide is a reference document. Using the table of content, WaterAid staff can navigate to a specific section of this document to find the information needed. For example, there is a section on useful approaches and tools in planning a sanitation programme, a section on the advantages and limitations of various treatment technologies, and a section on financing options. Throughout the document, there are examples of projects by WaterAid and others which can provide inspiration.

Who wrote it?

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It relied on the contributions, feedback and expertise from current and previous WaterAid staff including Dr Abdullah Al-Muyeed, Aditi Chandak, Dr Andrés Hueso, Anurag Gupta, Ellen Greggio, Farzana Ahmed, Hannah Crichton-Smith, Dr Joana da Cunha Forte, John Knight, Maya Igarashi Wood, Priya Nath, Puneet Kumar Srivastava, Dr Tommy Ka Kit Ngai, and consultant Sterenn Philippe.

1. Why FSM

1.1. The sanitation challenge

As of 2021, 3.6 billion people (or 46% of the world's population) still lack access to safely managed sanitation, as mandated in target 6.2 of the Sustainable Development Goals (SDGs). Of these, 1.7 billion suffer the indignity and risks of unsafe and unsuitable toilets, or do not have access to a toilet. The remaining 1.9 billion use toilets that leave human excreta uncontained and/or untreated, contaminating people and the environment, with severe health and economic consequences.

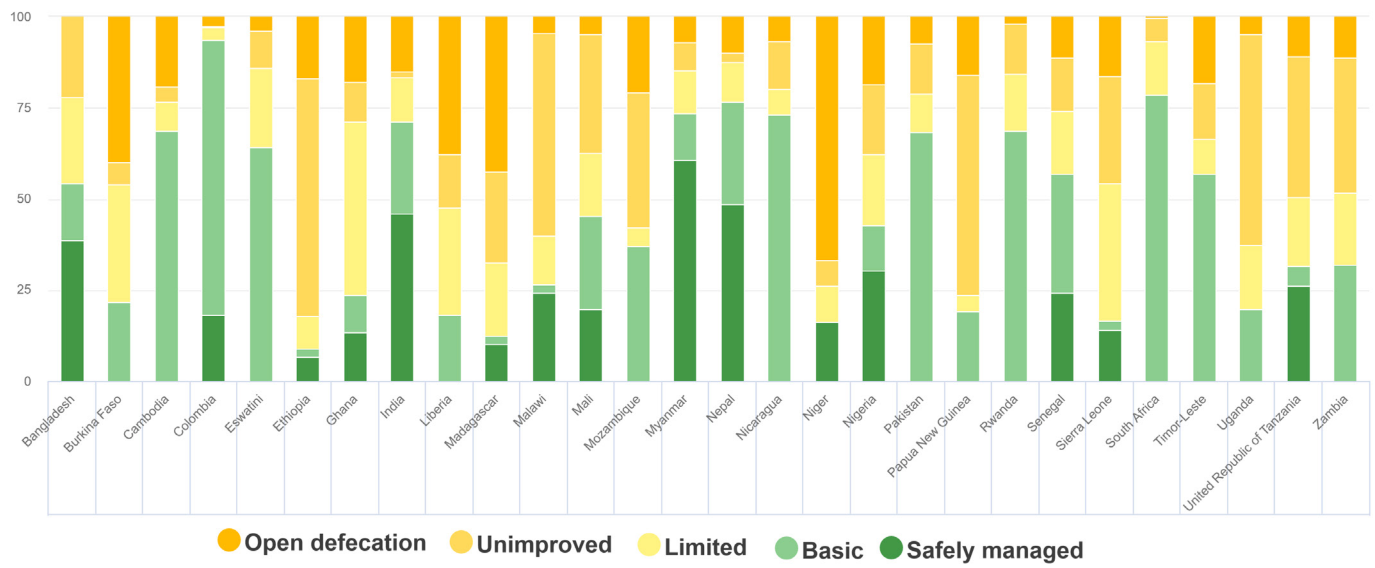


Figure 1: Sanitation levels in WaterAid countries in 2020 © WASH Data

This is particularly pronounced in denser settlements: large cities, informal settlements, peri-urban areas, as well as secondary towns – where urban growth is often the fastest – and rural areas that are gradually densifying.

There are many political, economic and social reasons behind the lack of progress on sanitation; when it comes to safely managing excreta, the default choice has often been sewers, which come with large capital and recurring costs. On-site sanitation, once seen as mostly rural, is now increasingly seen as a viable and even crucial sanitation solution. Yet it is still missing from many national policies, engineering curricula, and large financing streams.

1.2. Sanitation chains

A sanitation chain refers to the possible series of technologies and services to manage human excreta safely, along the following stages:

1. The **toilet** and often its associated **containment** (pit, tank, container).
2. **Emptying** that containment.
3. **Transporting** the excreta away
4. **Treating** excreta, and
5. **Disposing** of treated excreta, and/or **using** derived products.

Many chains exist (as described in the Compendium) but the most common are:

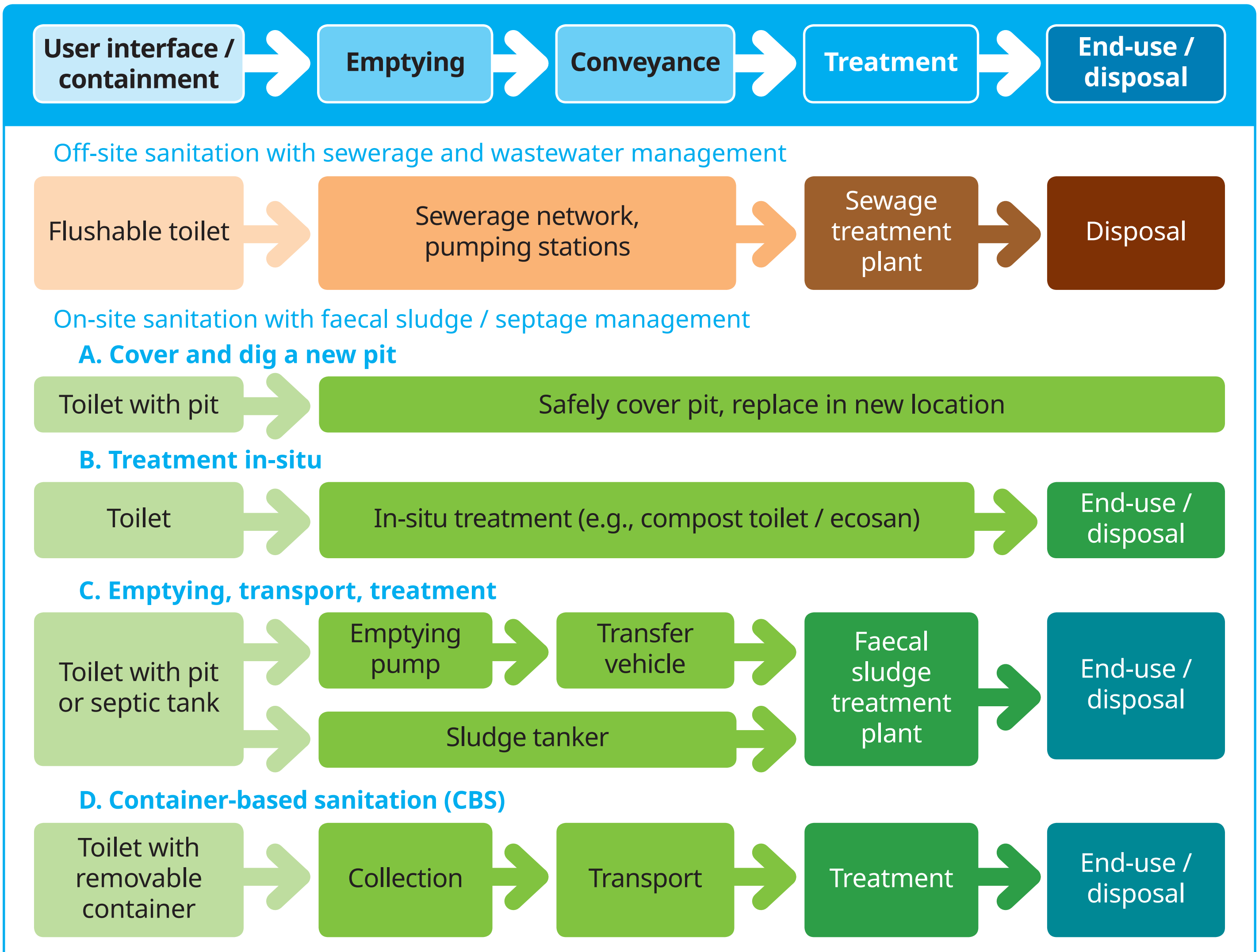


Figure 2: Possible sanitation chains

This document provides guidance on on-site sanitation chains, and does not address wastewater management, as these large systems are usually beyond WaterAid's remit, and are covered in classic sanitation engineering training. Sewerage also comes with very high capital, operating and maintenance costs, and high water consumption. Smaller decentralised solutions, often called DEWATS, can be appropriate if there is sufficient water, demand and expertise available – see WaterAid's Technical guidelines for designing decentralised wastewater treatment. CBS is more recent and is considered in section 3.2.5.

1.3. What is FSM?

Faecal sludge management (FSM) is the collection, transport, treatment and reuse or disposal of faecal sludge from pit latrines, septic tanks, or other onsite sanitation technologies.

Faecal sludge (FS) is the mixture of excreta, flush water and anal cleansing material that accumulates in the containment; it also often contains garbage thrown in the toilet, including menstrual products. Faecal sludge can range from solid (with waterless toilets) to more fluid (with septic tanks), in which case it is also called **septage**. FS is highly hazardous for human health and for the environment.

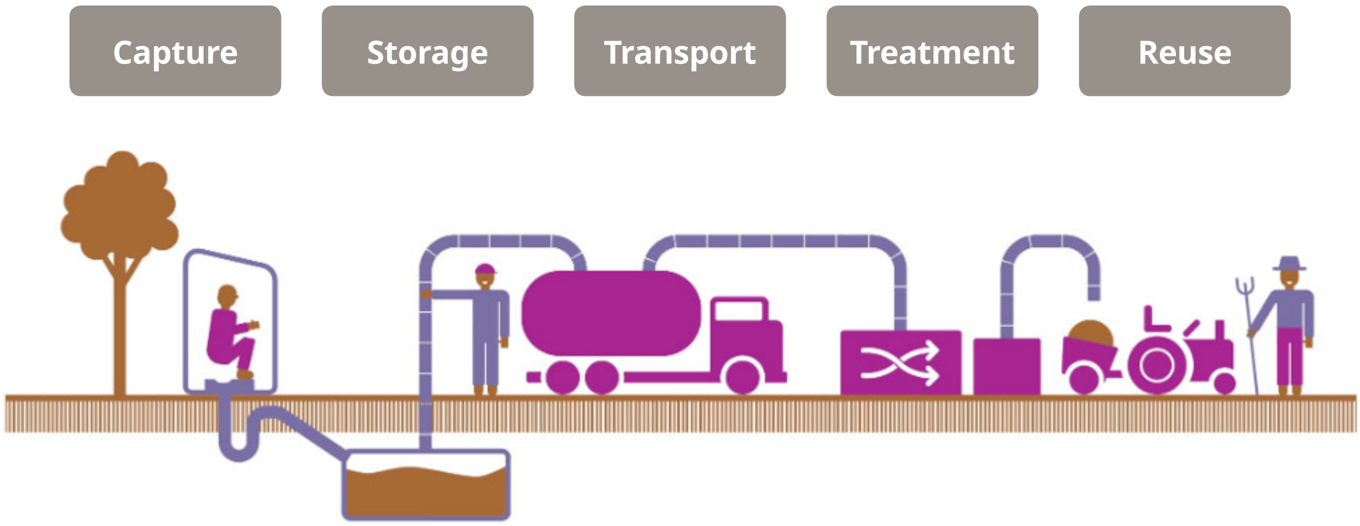


Figure 3: The sanitation chain © WaterAid

There are four broad options for FSM, which are considered in section 3 on technologies:

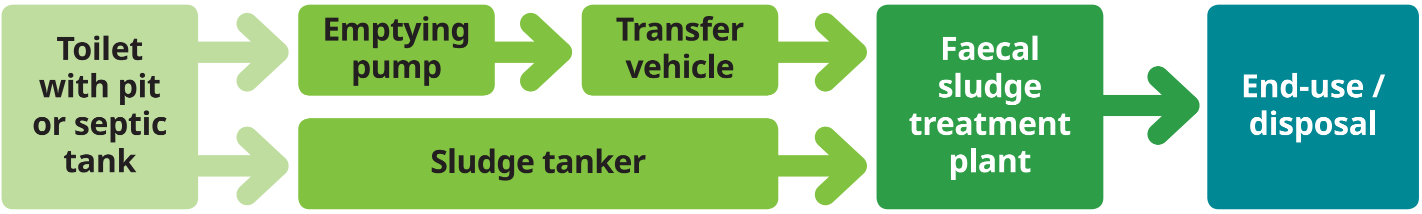
A. Cover and dig a new pit: For pit toilets: the full pit is covered, and another pit is dug. This can be appropriate in areas of low population density, and if there is a low risk of groundwater contamination.

Toilet with pit → **Safely cover pit, replace in new location**

B. Treatment in-situ: A toilet with integrated treatment, such as composting toilets or small biogas reactors, where treatment happens in-situ; the outputs still need to be used and/or disposed of safely.

Toilet → **In-situ treatment (e.g., compost toilet / ecosan)** → **End-use / disposal**

C. Emptying, transport, treatment: A toilet with a pit or septic tank, which requires emptying services when full to transport the content to a faecal sludge treatment plant, and possibly turn it into useful products. Emptying and transport can be done by a sludge tanker, or a dedicated pump and a transfer vehicle.



D. Container-based sanitation (CBS), where a removable container receives excreta and is regularly collected and transported to a treatment plant, and replaced by an empty container. Such containers are designed for regular removal, unlike pits.

Note that FSM and domestic solid waste management are related but separate components of environmental sanitation: whilst they may fall under the responsibility of the same authority, they rely on different technologies, chains, actors and economics. However, from a reuse perspective, it is possible to envisage an integrated management of these two types of waste with the objective of co-processing and energy production, for example.

1.4. When is FSM needed?

FSM is needed whenever the main alternative – sewerage – is not available. The actual chain depends on the context: In urban areas, the City-Wide Inclusive Sanitation (CWIS) principles recommend looking at a mix of technical solutions and not prescribe a single one; both systems often coexist in the same city but would be appropriate for different areas. In rural areas, the population density and other geographic characteristics often govern what is possible. This is detailed in the following section.

2. Principles, approaches and tools

2.1. WaterAid's position and approach

WaterAid's sanitation framework requires "Safely managing services along the entire sanitation chain from capturing, containment, treatment on-site/transporting and treatment offsite – to effective safe disposal or reuse of excreta". WaterAid's urban framework also highlights hygiene and sanitation as priorities, given the neglect this area suffers.

We take a systems strengthening approach to sanitation: this means identifying the actors (people and institutions), factors (social, economic, political, environmental, technological) and the interactions between them, that influence the safe management of excreta. This requires us to identify where weaknesses exist and work with a range of actors along the sanitation chain, and at multiple levels, to address them. This can include working with public and private service providers, regulators, community members, policy- and lawmakers.

2.2. Quality Programme Standards

WaterAid's Quality Programme Standards (2018) are directly relevant to prepare FSM strategies, programmes and projects.

Examples of WaterAid standards closely related to FSM

Minimum standards

M4.1 We will consider **sanitation as a service along the whole chain**, from toilets to safe disposal and, where appropriate, reuse of excreta.

Full standards: Strategic, Programme and Project-level

S4.5 We will support local governments and private sector stakeholders to develop **viable business models** for sanitation services, where applicable (for example, in urban environments).

S4.6 We will support national and local governments, where they are the most viable option, to provide efficient **public sanitation management services.**

PG4.7 We will support **local private sector participation** in the delivery of sanitation services and products, including FSM.

PG6.2 Our guiding principles for urban programmes [include] **prioritisation of sanitation and hygiene** in urban plans and budgets.

PJ5.4 We will not support construction of latrines or sanitation projects in areas where this is likely to contaminate water sources.

2.3. Urban approaches and tools

There are many approaches and tools used in the urban sanitation sector, which we compared in 2016 (English and French); we also analysed when they are most relevant, depending where a given city is in its sanitation journey. The more recent publication A sanitation journey goes deeper into the history of urban sanitation approaches; below are some common ones used by WaterAid.

2.3.1. Sectoral approach: City-Wide Inclusive Sanitation (CWIS)

City-Wide Inclusive Sanitation is a framework that was co-developed by a few organisations in 2016, including WaterAid, the World Bank and the Bill and Melinda Gates Foundation (BMGF). It aims to support city and town authorities in planning sanitation services. It is well-aligned with WaterAid's systems strengthening way of working and our urban principles.

CWIS initially comprised of four principles in 2016, then six "Manila principles" in 2018. The most recent and most widely used CWIS framework includes three services outcomes and three system functions, with corresponding indicators and monitoring:

Service outcomes	**Equity** Services reflect fairness in distribution and prioritisation of service quality, prices, and deployment of public finance/subsidies	**Safety** Services safeguard customers, workers, and communities from safety and health risks – reaching everyone with safe sanitation	**Sustainability** Services are reliably and continually delivered based on effective management of human, financial and natural resources.
System functions	**Responsibility** Authorities execute a clear public mandate to ensure safe, equitable, and sustainable sanitation for all	**Accountability** Authorities' performance against their mandate is monitored and managed with data, transparency and incentives.	**Resource planning and management** Resources – human, financial, natural, assets – are effectively managed to support execution of mandate across time/space.

In practice, organisations use CWIS principles in various ways, and some cities have started branding their work as "CWIS" when they use innovative solutions, implement FSM and/or reach informal settlements. This framework can be used for advocacy as it carries the legitimacy of many partners, and allows us to check if our urban sanitation plans are well positioned or if we are missing any key aspects.

CWIS does not prescribe a specific form of sanitation, but makes it clear that a variety of chains are usually needed to serve all residents.

Further resources

- BMGF CWIS website, monitoring dashboard, and open access article
- World Bank CWIS website and open access article
- Official CWIS website where you can access myth-busting videos

2.3.2. Analysis tool: Shit-Flow Diagrams (SFD)

The first step of a municipal sanitation programme is usually a situation analysis. Few cities know how well their sanitation services are performing, or they usually only know the status of treatment plants and a rough estimation of toilet coverage. A popular tool is the Shit-Flow Diagram (SFD, also called Excreta Flow Diagram). WaterAid has produced SFDs in more than 25 towns and cities, many of them through a GIZ-funded programme in 2018-19.

SFDs consist of a short report along with a diagram showing the proportion of excreta that is safely managed (green) or not (red) along the sanitation chain and for the whole city or town. There are several "levels" of SFDs, from lite to comprehensive, depending on the amount of work involved and access to precise data. Most SFDs except "lite" ones include a service delivery assessment as well, in line with WaterAid's systems strengthening analysis.

The results are often surprising: authorities typically find a discrepancy between a high population having a toilet, but a low proportion of excreta being safely managed. The proportions are not scientifically measured, but instead inferred from published data, interviews with key stakeholders, focus group discussions and visits.

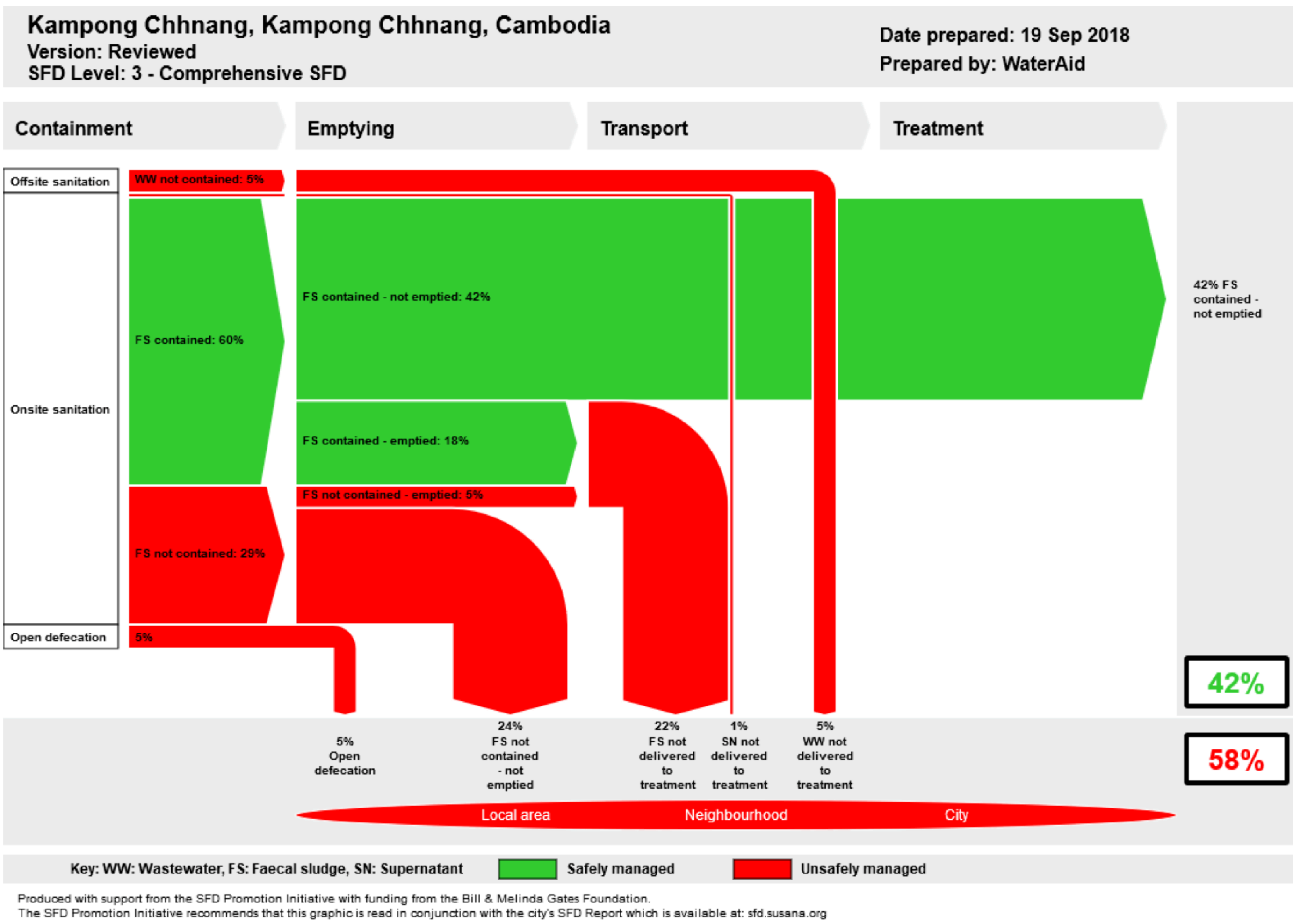


Figure 4: The Kampong Chhnang SFD in 2018 © WaterAid/SFD-PI

The objectives of SFDs are to

- Create awareness on city-wide sanitation issues instead of localised ones.
- Communicate easily about the city sanitation situation, especially with local media and community advocates.
- Engage city stakeholders in a coordinated dialogue about excreta management (SFDs have proven to be an effective political tool).
- Provide a baseline for engineers, planners and decision-makers to start planning, and to monitor progress.
- Give an indication of the public health hazard posed by excreta.

Advantages

- 'Lite' SFDs are quick to produce (a few days), and even 'comprehensive' ones may only require a few weeks for visits, interviews and write-up, requiring minimal funding.
- They are now well-established in the sector and known by most funders and actors. Training is readily available within WaterAid and from the official SFD portal. Some countries are considering using them to monitor how "safely managed" sanitation is as part of JMP reporting.
- They allow you to create links with the main sanitation stakeholders in a given city and bring them together during a feedback workshop.

Limitations

- Amongst other limitations, SFDs will not tell you whether the identified hazards are indeed significant health risks for the residents (something that SaniPath can do at the scale of a neighbourhood).
- SFDs do not yet say whether sanitation workers enjoy decent living conditions – though WaterAid has proposed a methodology associated with SFDs.

Further resources

- WaterAid's internal SFD page including all SFDs done by WaterAid and training.
- A blog highlighting some lessons from our programmes.
- The official SFD portal which includes all finished SFDs, manuals and training.

Case study 1:

City-wide analysis in Nigeria

WaterAid Nigeria commissioned a context analysis of urban sanitation in Enugu, Kano and Warri in 2019. The study used elements of SFDs and other tools, and was part of a commitment to support states and cities to utilise the National Action Plan. The study highlighted the lack of safe management of excreta and the lack of institutional responsibility for FSM.

2.3.3. Planning approaches

While a sanitation plan is not necessarily the only way to generate progress, and while plans are rarely blueprints that will be followed to the letter; the planning process is a great way to mobilise various stakeholders towards a shared goal, and to explore linkages with other sectors. The planning process would ideally:

- **Engage residents** actively and ensure all voices are heard, especially those more excluded.
- **Take stock of which solutions already exist,** even if informal or illegal, as with manual pit emptiers or community toilets.
- **Link with other sectors** to better understand dynamics affecting FSM, such as planning (to understand tenure issues), housing, and other infrastructure services such as solid waste management.

Case study 2:

Co-creating a sanitation and hygiene plan in Babati, Tanzania

An action research project in the secondary town of Babati in Tanzania used a participatory approach to create a sanitation and hygiene plan for the town, by actively involving local stakeholders. It was the result of a partnership with academics and local authorities, and used various tools such as Shit-Flow Diagrams, political economy analysis and scenario planning to consider various possibilities. This allowed the municipality and the utility to take ownership of the resulting action plan and business plan, and to make sure that the scenarios considered were appropriate for the residents. More information in a learning note and on the Babati page.

The planning process can produce, for instance:

- An analysis of the current situation, including root causes of poor service levels and especially considering inequalities and exclusion.
- Proposed solutions, for instance for different geographies of the area considered (informal settlements, different topographies...)
- Governance and management arrangements, including accountabilities.
- A business and investment plan that clearly defines the costs of the action plan, the human resources and capacity building needs, the funding avenues as well as a phasing plan for the implementation of the activities.

Key planning resources

- A District-level roadmap for sustainable sanitation by Agenda for Change.
- An example citywide inclusive plan in Malindi by WSUP.
- India's Toolkit for district-level officials on FSM, 2021 (archived version).
- **CLUES**: A well-structured approach to sanitation planning, used in Nepal and India.

Case study 3:

Lessons from building FSTPs in Bangladesh

In Bangladesh there are plans to build 100 Faecal Sludge Treatment Plants (FSTPs) in secondary municipalities. Research in 2019 considered the lessons of previous FSTP development, by analysing four older FSTPs in secondary towns. At the time of the research, only one plant was still fully operational, one not operating, and two only partially.

A challenge identified was that the FSTPs were not part of an integral and well-thought-out plan considering the whole sanitation service chain. Unbalanced partnerships between stakeholders were a crucial barrier, as they hindered the empowerment of the municipal governments to take ownership of FSM service provision. The municipal financing and technical capacities were another barrier, which was covered by NGOs in the most successful plant.

The study suggests that future investment in FSM in secondary towns should:

1) Put municipalities in the driving seat,
2) Ensure adequate financing,
3) Consider the whole sanitation service chain, and
4) Strengthen the capacities of local actors to deliver FSM services.

2.3.4. Other notable tools

There are many tools available for assessing, prioritising, planning and costing FSM. Many can be found in the FSM Toolbox for assessment and planning. Some notable ones include:

- **Sanitation Safety Planning (SSP):** A process proposed by WHO that brings health and sanitation sectors together to map contamination pathways and highlight risks and priority intervention areas. WaterAid used SSP in Bangladesh.
- **SaniPath:** Used to assess exposure to contamination, to identify priorities for sanitation investments or interventions. WaterAid used SaniPath in Cambodia.
- **CWIS costing tool:** Used to assess the cost of various sanitation service options.
- **CWIS Services Assessment and Planning:** A tool set up by BMGF that lets you enter baseline values (e.g., from an SFD) for a given city and analyse the outcomes of various scenarios and investments. It has been used by a few pilot cities and by ESAWAS (Eastern and Southern Africa Water and Sanitation).

2.4. Rural FSM

FSM has long been considered an urban issue, especially for large cities. As many rural areas are becoming more densely populated, and as access to basic sanitation is improving, the need and demand for full sanitation chains are increasing.

In lower population-density areas, some simple solutions may be appropriate, such as digging a new pit when one is full, or twin-pit toilets (see section 3.2.3). Rural areas with higher population density gradually need emptying and treatment services, but these may not yet be economically viable due to the long distances between customers and treatment/disposal sites. Rural FSM projects and research are increasing, especially in South Asia.

Useful resources

- WaterAid India published a **Strategy for FSM in rural India**, presenting the various geographies (such as urban-like settlements, dense rural areas, cluster of villages, sparse, etc.), related objectives and financing options. WaterAid India has also developed rural treatment plants to showcase technical possibilities.
- WaterAid's Rethinking Rural Sanitation guidance also distinguishes various rural typologies and several possible sanitation solutions for each one. Its costing framework includes a sanitation service chain component.
- The pS-Eau did a review of sanitation services in small towns in 2018, looking at the rural and peri-urban interface.
- Note that SFDs have not yet been used for rural settings; they are best used for a more delimited urban area, even if for a small town.

3. Technical aspects: choosing sanitation technologies

This section shows what FSM can look like in practice, through a selection of technologies and suggested decision criteria relevant for WaterAid. For a more complete list of FSM technologies, please refer to the comprehensive overview in EAWAG's Compendium of Sanitation Systems and Technologies, along with the more recent Guide to Sanitation Resource Recovery Products & Technologies. These technologies must be selected based on several factors including costs, revenue, management models, which are described in section 4.

3.1. Overview and decision criteria

There is no single "right" solution for a given context, but there are four broad options (see section 1.3), and many technologies to choose from in each. An overall principle is that the whole sanitation chain must be considered, to minimise the risk of health hazards and environmental damage at each stage.

The following criteria should be used when choosing FSM solutions in a given context:

What already exists

A proposed solution should build upon the current sanitation chain, even if unsafe or inadequate. This is especially the case if the present situation is the result of mobilised communities. Imposing a completely different solution should be avoided.

Demand, use and practices, including:

- Whether the chain will be used by homes and/or institutions like schools, health centres, marketplaces, etc.
- Existing and potential demand for reuse products, such as local agriculture.

Socio-economic aspects

- Population and density.
- Tenure: whether residents are property owners, tenants or squatters, and can potentially do improvements.
- Affordability and willingness to pay, and possibly the need for subsidies.
- Cultural attitudes, taboos and practices around excreta and sanitation.

Capacity and resources required

- Skills and human resources to build, operate, maintain and regulate the infrastructure and equipment, while ensuring the health and safety of operators.
- Available local technologies, depending on the supply chain.
- Energy and water requirements.
- Land availability.

Costs and revenue

Including capital costs (CapEx), operational expenses (OpEx) and capital maintenance expenditure (CapManEx, e.g., full replacements of infrastructure) and support activities costs – more in section 4.1 on financing.

Incremental improvements

An initial solution can be relatively simple but may require improvement works to enable more advanced treatment later.

Geographical parameters, including:

- Temperature, as low temperature can inhibit many treatment processes
- Rainfall and humidity, which affect the quantity of water
- Road accessibility, governing which vehicles can access
- Depth of groundwater and direction of its flow
- Soil and topography, including infiltration properties and distance to water points
- Flood risks and adaptation needs

Many climate parameters can be obtained from FAO's tool CLIMWAT. Groundwater information usually comes from national databases, and regional databases such as the Africa Groundwater Atlas.

Greenhouse gas emissions

WaterAid's climate focus is mostly on adaptation, but some FSM operations can be very carbon-intensive, especially the operational emissions (such as trucks with Diesel engines going to distant treatment sites), methane production, and embodied emissions from large concrete installations. Methane is a large contributor to the global crisis: pit latrines contribute 1% of global emissions.

Some treatment methods can significantly reduce emissions, such as using biogas and composting (which can reduce emissions by one to two orders of magnitude), and regularly emptying pits and septic tanks. The ECAM tool (Energy performance and Carbon emissions Assessment and Monitoring) can be used by utilities for a detailed assessment of emissions. For a quicker comparison of emissions by technology types, see the CACTUS project.

3.2. Toilet and containment

The **containment** is the pit, tank or container that will hold the faecal sludge. The names used vary from place to place, but typically:

- A **pit** is a hole in the ground, which can be lined for more stability; typically, most of the liquids infiltrate into the ground below.
- A **tank** should be sealed so that the liquids only come out of an outlet, as with a septic tank or the vault of a composting toilet.
- A **container** is designed to be replaced periodically, as part of CBS.

Together, the toilet and the containment are usually the responsibility of the user (household or institution), and not of the service providers. FSM service providers, such as emptiers, do not usually provide services to construct toilets or containment. However, poorly located and designed containment is a frequent source of groundwater contamination (and hence nearby drinking water sources). Containment is a critical component in achieving safely-managed sanitation – because it is the user's responsibility it is also often over-looked and harder to address.

Toilets and containment significantly determine the type of faecal sludge and therefore the appropriate collection services. However, in some cases, the treatment can be achieved in the containment (as with ecosan), reducing the need for FSM services.

3.2.1. Toilets and FSM

The toilet itself is not usually the main focus of FSM, which is more concerned with the later stages of the sanitation chain. In many cases, the toilet and the containment form part of the same technology: for instance, a squat pan on a slab over a simple pit, or a flush toilet with a siphon leading to a septic tank.

There are already many guides to select, design and construct toilets, varying from country to country. For FSM, what matters is:

- Whether the users have the power and resources to maintain, repair and improve it. For instance, tenants and squatters usually have limited choice and may not be able to afford formal pit emptying.
- What enters the containment in addition to excreta: anal cleansing materials such as paper or water, solid waste, menstrual materials. Providing female-friendly toilets for example, can help reduce the presence of menstrual products in pits.
- How much flushwater enters the containment, varying from less than a litre to more than 10 litres per flush. This depends on water available and whether the toilet is fitted with a water siphon, a low-flush pan like the SaTo Pan, or a direct hole.
- Access to the containment for emptying.
- Whether emptying is needed, as with composting toilets.

And while not crucial for FSM specifically, the following is essential for universal access:

- Whether the toilet is "improved", i.e., ensures safe separation of excreta from users and from vectors such as flies, and allows easy cleaning.
- Whether it is accessible, affordable, and appropriate for all users, irrespective of gender, age or disability.

3.2.2. Pits

A pit is a hole, usually dug manually, which will contain the faecal sludge. This includes excreta, flush water and anal cleansing materials, plus other material thrown in it. Most of the liquids infiltrate into the ground below the pit.

Pits are most common in rural areas and small towns but are also common in large cities in the absence of alternatives, for instance when there is insufficient space for septic tanks. Pits can be:

- **Lined,** with waterproof walls, or **unlined,** depending on the risk of soil collapse.
- **Directly under the toilet,** especially for a dry toilet, or **offset,** with a pipe leading from the toilet to the pit, which is possible if water is used for flushing. Offset pits can be easier to access and empty.

Pits eventually fill up: humans produce between 100g and 500g of faeces and 1 litre of urine per day, but the actual accumulation rate of faecal sludge can vary depending on how liquids infiltrate (itself depending on the type of soil, depth and lining of the pit), whether water is used for flushing, the method of anal cleansing, and the rate of sludge decomposition. Typical accumulation rates vary:

Facility	Litres / user / year
Sludge in household pit latrine	40 to 90
Septage in septic tank	350
Sludge in public toilet (with flushwater)	700

Table 1: Example sludge accumulation rates (source 1, source 2)

Options to deal with full pits include:

Safely cover and dig a new one

This is the easiest and cheapest option, possible when:

- Land area is sufficient, typically areas with low densities.
- The superstructure can be moved or replaced easily.
- There is a low risk of groundwater contamination.

This last point depends on the soil permeability, the depth of the aquifer, the distance to the groundwater sources, and whether these sources are protected. One way to estimate this is to use the SFD groundwater pollution assessment tool, or the annexes in WaterAid's guidelines for construction of institutional and public toilets.

Emptying when full

This is required for septic tanks (and many countries have regulation mandating certain emptying frequencies), and for pits when population density or soil conditions prevent digging a new pit, as is typical in most urban areas (see section 3.3 on emptying).

Treatment in situ

The following section shows how some technologies avoid the need to transport faecal sludge far away for treatment.

3.2.3. Treatment in-situ: twin pit and ecosan

Some containment technologies allow partial or full treatment of the faecal sludge.

Twin-pit toilets

In this instance, two one-cubic-metre pits are dug; a pipe leads from the toilet to a diversion chamber, and then to one pit. When that pit fills up, the flow is diverted to the second pit. When the second pit fills up, the contents of the first pit has turned to humus[1] and is usually by then safe to dig up – provided proper design and operation. The treated faecal sludge can then be used as a fertiliser and soil conditioner[2] to grow crops.

This option can be safe if some of the liquids can infiltrate in the soil without contaminating groundwater, and the remaining faecal sludge has enough time to decompose and pathogens to die (at least one year, ideally two years). Twin-pit toilets require more space and investment than a single pit toilet but require less maintenance over time.

This option is often used in South Asia and has been promoted as part of national initiatives. See this SSWM guide and attached presentation for an overview.

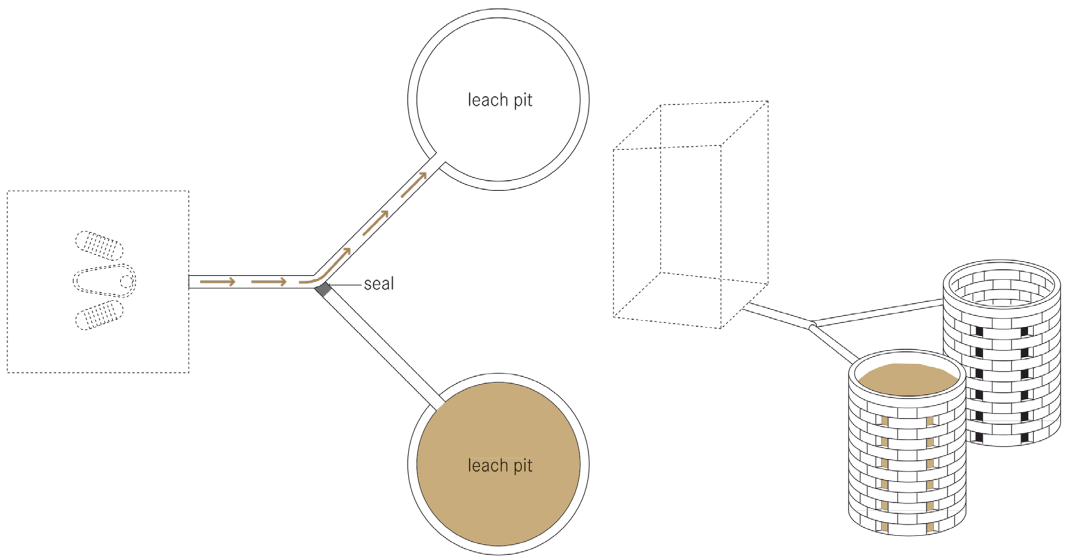


Figure 5: Twin-pit toilet diagram, CC-BY EAWAG

[1] Humus and compost are often used interchangeably to refer to decomposed organic matter. Humus typically refers to the product of aerobic and anaerobic digestion happening in double pits; compost results from a controlled aerobic digestion process. Although they look similar, humus may still have pathogens and has more variable quality (source)

[2] Fertilisers are any materials applied to soil mainly to supply some of the essential nutrients needed for plant growth. Soil conditioners mainly improve the soil's physical condition (structure, water infiltration) (source)

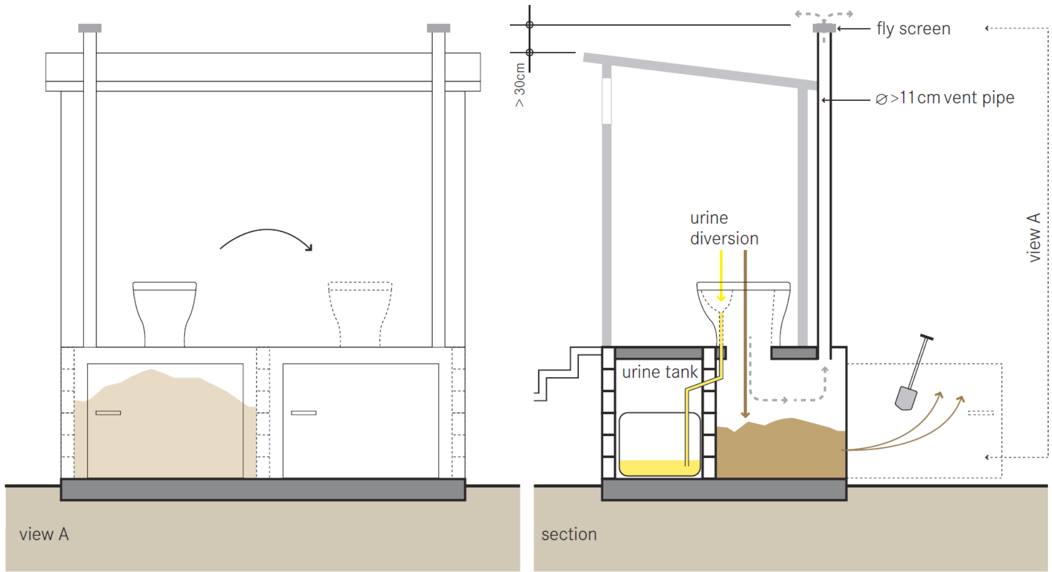


Figure 6: UDDT diagram, CC-BY EAWAG

Ecosan

There are many types of composting toilets or "ecosan toilets", but the most common is the urine-diverting dry toilet (UDDT).

With this technology, the toilet seat or pan separates urine, which can infiltrate the soil or be collected and used for fertilising plants. Faeces go into a vault, which is sealed when full while a second one is used. Faeces turn into compost, which can then be used as fertiliser or soil conditioner.

Compared to twin-pit toilets, UDDTs do not require pits to be dug (as the vault is usually above ground for easier access), and require less time, as the drier and hotter conditions inside the full chamber speed up the decomposition process.

Their disadvantages are:

- They can be more expensive to build.
- They usually need to be elevated and can be less accessible, with a ramp often unaffordable for household toilets.
- They need behaviour change to use urine-diverting pans, not use water for flushing, and correctly direct anal cleansing water.
- They require urine disposal, usually by infiltration, which is not always possible in rocky soil or densely populated areas.

For these reasons, many ecosan toilet projects have failed to remain sustainable without regular NGO intervention. Composting toilets tend to be more suited for areas:

- where setting up emptying services can be complex,
- where there is local demand for the resulting compost,
- where water is scarce, and rocky or flood-prone areas.

Case study 4:

Eco-toilets by WaterAid India

WaterAid India has developed alternative ecosan toilets for rural areas, especially for flood-prone, high water table, rocky or hilly areas.

Bio-toilets have three underground chambers. In the chambers, the Microbial inoculum bacteria speed up decomposition and poly-grass mats on the chamber walls help bacteria to multiply. Wastewater from the toilet is gradually cleaned from one chamber to the next, until the effluent coming out of the third chamber can be infiltrated or reused for irrigation.

Evapotranspiration toilets rely on plants absorbing wastewater through their roots and evaporating the water through their normal respiration; Wastewater from the toilet flows through an underground "tank" built from old tyres, surrounded by layers of stones and sand. WaterAid India has conducted about 20 trials of this technology.

See: WaterAid India's FAQ and related article; and internal WaterAid guidance.

Figure 7: the bio-toilet's three chambers

Figure 8: Schematic of an evapotranspiration toilet, CC-BY-NC-SA India Water Portal

Tiger Worm Toilets

These recent toilets rely on vermicomposting in the pit itself: earthworms (such as Tiger Worms, hence the name) decompose faecal matter quickly and turn it into vermicompost, which is safe to handle. They also reduce the rate at which sludge and compost accumulates in the pit. If well maintained, the worm colony can in principle remain in the pit indefinitely.

They have been piloted in some disaster and post-disaster situations by Oxfam in six countries. Oxfam has published a detailed manual. The main limitation of these toilets is the need for specific skills, including external specialists, to install the toilets, and for proper operation and maintenance afterwards.

3.2.4. Septic tanks

A septic tank is an underground fully lined (waterproof) tank, divided into two chambers, which receives excreta, anal cleansing materials and flushwater from the toilet. It provides some treatment: solids settle at the bottom, forming **septage**, and the liquid portion, called **effluent**, is discharged from the tank outlet.

A septic tank provides only partial treatment:

- Septage needs to be pumped out regularly, as too much septage prevents efficient treatment and can block the effluent pipe; however, in practice many users wait until the tank starts to malfunction.
- The effluent going out is still contaminated: it needs to infiltrate into the ground though a soak-pit or an infiltration pipe, or be conveyed to a treatment plant.

The size of the septic tank is determined by the number of users, the minimum retention time (wastewater needs to remain in the tank for about 48 hours to ensure the proper separation of solids); and the time interval desired between emptying. WaterAid's guidelines for construction of institutional and public toilets annexes have details, drawings and calculators for septic tanks. Oxfam's septic tank guidelines also provide quick sizing calculations.

Many countries have standardised septic tank requirements in their regulations, and often have manufacturers providing prefabricated tanks, often cheaper to install. In practice, many such tanks are called "septic tanks" but have been poorly designed and constructed. For instance, they may not have an outlet and require very frequent emptying; they may not be fully lined, or have cracks, causing leaks into the surrounding soil; they may have just one chamber, causing some solids to block the effluent pipe. Residents may not be aware of this if it was constructed before they moved in. See this review of septic tanks in India for examples of regulation and actual practice.

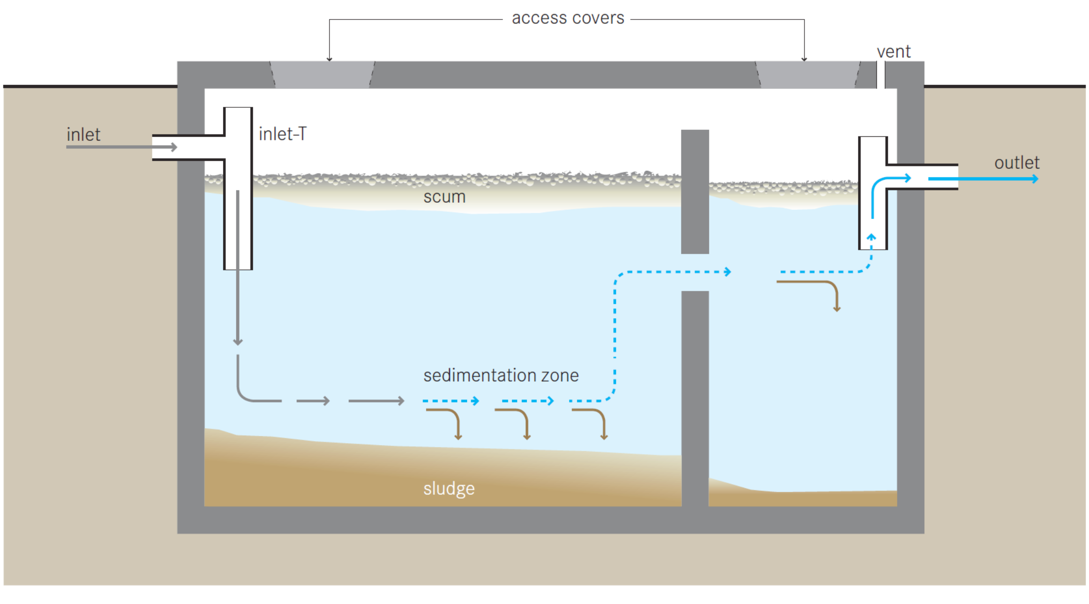


Figure 9: Schematic of a septic tank CC-BY EAWAG

3.2.5. Container-based sanitation (CBS)

CBS refers to toilets in which a removable cartridge, usually called "container", is used to collect excreta under the seat. The container is collected when full, or at regular intervals, and replaced with an empty, clean one.

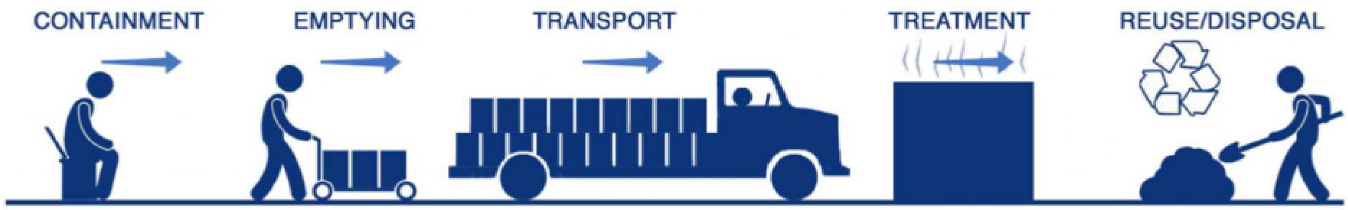


Figure 10: The CBS chain © CBSA

This approach has mostly been used by NGOs and social enterprises, and a few public operators, many of which are part of the Container-Based Sanitation Alliance (CBSA). There is a wide variety of technologies to ensure cleanliness of the toilet and sometimes separation of urine and faeces. CBS can be well suited for:

- Very high population densities such as informal settlements, as the toilet can be placed inside a dwelling.
- Tenants, who do not necessarily have the ability to install a permanent toilet.
- Very low-income areas, where a small regular payment can be preferrable to a larger upfront investment.
- Areas with a high water table and/or at risk of flooding, as there is no need for a pit.

The main limitations of this model are the reluctance of many authorities to accept it, given its similarity to older unsafe "bucket toilets", which were emptied by hand without protection; and the different funding it requires (more operational subsidies and less capital funding than other sanitation chains). There is ongoing work to measure and promote the safety of CBS.

For an overview of the business models and technologies in CBS, refer to the 2018 World Bank assessment and the 2021 CBS implementation guide.

3.3. Collection and transportation

Faecal sludge can be removed from pit and septic tanks using different equipment, from large sludge tankers with powerful pumps to smaller handpumps and carts.

The choice of technology depends on:

- **The type of containment:** pit or septic tank, and whether it was designed to be emptied (access cover, offset from the toilet). Without an access cover, the slab may need to be broken.
- **Access to containment:** for instance, road access or narrow pathways within an informal settlement.

- **The thickness of the sludge:** depends on whether water is used for flushing and/or anal cleansing, whether the containment allows liquid to infiltrate into the ground, and how long sludge has been in the pit. Very solid sludge may not be pumpable, but can be diluted with water poured into the pit (when the sludge is very solid then pressurised water is sometimes used to help break-up and fluidise it). There are formal methods to analyse the characteristics of the faecal sludge.
- **Solid waste content:** especially for dry toilets without a siphon. It is common to find solid waste thrown in pits, including large objects (like bags), objects that are difficult to remove (like rags), and medical and hazardous waste (syringes, condoms, menstrual products…). Such objects may need emptying ahead of the sludge, a practice called **"fishing"**, often conducted with hooks and rods.
- The **cost** of emptying and **who pays for it.**
- Availability of technologies and supply chain.

This stage of the sanitation chain is often a big health and safety hazard for residents and for workers. In the absence of formal emptying services, residents may rely on very unsafe methods. This includes making a hole in the side of the pit during the rainy season to discharge its contents onto the street, or paying informal manual emptiers to empty the contents in unsafe ways. A goal here must be to safeguard the health and safety of residents and workers.

Case study 5:

Sanitation workers: health, safety and dignity

All sanitation workers are exposed to health and safety hazards, but informal manual emptiers suffer much higher risks, especially in the absence of personal protective equipment (PPE), insurance and protection. Despite providing an essential service, they are often stigmatised, and may be considered illegal.

In 2019, WaterAid, the World Bank, the WHO and International Labour Organisation (ILO) started an initiative to look at the health, safety and dignity of sanitation workers. The recommendations include:

- Ensure their safety through training, access to PPE, improved policies and guidelines.
- Improve their working conditions through access to health insurance, social security, decent wages, and financial support.
- Provide recognition of the workforce by prioritising their rights, making sure they are seen as key workers, and challenging deep-rooted inequalities and discrimination.
- Support their empowerment through training and education opportunities and making sure they are included in consultations with local authorities.
- Encourage research to better understand the sanitation workforce, their challenges, the power dynamics and causes of discrimination, and safety requirements.

When considering FSM improvements, specific activities can include:

- Consulting existing sanitation workers.
- Ensuring their health and safety in any planned technology or service.
- Consider how any planned change will impact their livelihoods, and plan for this transition.

3.3.1. Sludge tankers

Sludge tankers, also called vacuum trucks, are the most common emptying technology used for pits and septic tanks in higher-income countries. They work best with septage and liquid sludge from wet pits. They can be efficient by emptying several tanks or pits in a relatively short time before going to a treatment or disposal site.

However, such trucks are large, and expensive to buy and maintain. Ageing trucks can often break down and consume a lot of fuel. The distance to the disposal or treatment sites increases the cost of the emptying service, increasing the service rate for residents. Therefore, this service usually requires subsidies by local authorities.

Sludge tankers are usually too large to enter the narrow lanes of informal settlements, and often cannot access unpaved roads in rural areas. For these reasons, they are often not physically and financially appropriate for informal and low-income areas. Smaller sludge tankers exist, especially in South Asia, which can be more appropriate for small towns. For instance, IRC has documented the potentials and limitations of "honey-suckers" in Bengaluru, India. Otherwise, emptying must be done with smaller pumps and alternative transport.

3.3.2. Smaller pumps

Figure 11: Sanitation workers in Dar es Salaam, Tanzania, operating a Gulper

If sludge tankers are unaffordable or cannot access a facility, the alternative is to use smaller pumps. They usually pump faecal sludge into smaller vehicles equipped with a tank, or into containers which can be loaded onto small vehicles.

Many affordable pumps have been and are still being developed, from simple handpumps like the Gulper to small, motorised pumps like the Excluder also called Flexcrevator, the PuPu Pump, etc. Similarly, many vehicles are possible, from trailers and carts to motorised tricycles. Comparisons includes:

- The FSM Alliance Practical Guide to Available Pit-Emptying Technologies, 2022
- WASTE investigated desludging for difficult areas in 2015.
- GOAL's comprehensive review of technologies for Freetown in Sierra Leone in 2016.

There have been many failures concerning smaller pumps, usually due to poor business models. Many pumps were designed for technical efficiency rather than efficient use by the small businesses typically involved in emptying and transportation services. For instance, the Vacutug failed because its single motor, both powering the pump and moving the tank, would take several hours to reach a disposal site. The MAPET required a team of three operators, making it expensive to run.

Even if the only feasible option, this form of emptying has limitations:

- It can be slow and labour-intensive, increasing the costs. The speed and distance to treatment or disposal sites is often a critical factor.
- It can be harder to offer good protection from sludge when emptying or removing solid waste compared to sludge tankers.
- The barrels full of sludge present hazards: the sloshing of the contents can cause the vehicle to topple over, and hot conditions can cause the barrels to open unexpectedly due to gas production.

Case study 6:

WaterAid Tanzania's experience with the Gulper

WaterAid Tanzania has piloted several ways to support small businesses to provide pit emptying services in Dar es Salaam. They have tried technologies such as motorised tricycles for transport, barrels and small tanks, and the Gulper pump. The Gulper works on the same concept as a direct-action water pump: the handle is pumped by hand, the sludge rises through the bottom of the pump and is forced out of a spout. It can be made locally with a PVC tube, steel rods and valves. The bottom of the pipe is lowered down into the pit while the operator stays at the surface to operate the pump, thus removing the need for someone to enter the pit. The sludge discharged can be collected in barrels or carts, and removed from the site safely.

WaterAid Tanzania has also tried various financial support mechanisms, and ways to engage communities to promote the service. See the various business models used in this project.

3.3.3. Transfer stations

Sludge transfer stations divide the transport process into two stages:

1. Emptiers use carts or small vehicles to transport FS from the point of collection to a nearby transfer station.
2. The transfer station is then emptied by a sludge tanker, and the faecal sludge is transported to a final disposal site.

This approach can be useful in densely populated informal settlements, and when treatment sites are far away, but requires regular emptying, as a full transfer station can be a smelly nuisance for neighbours.

SNV published a guide and a shorter learning brief on transfer stations.

Case study 7:

Examples of transfer stations from Maputo

In Maputo in 2010, WSUP and WaterAid supported a community-based organisation (CBO) to empty local pits with small sludge tankers, which are in turn emptied into neighbourhood transfer tankers, at a site designated by the CBO. The CBO relies then upon the municipal services to empty the transfer tank, however institutional capacity and coordination of these activities remained weak. To maintain the FSM chain, WaterAid provided a local association with a truck that removes the full transfer tanker and replaces it with an empty one.

SEED / WSUP (2011) Formulation of an outline Strategy For Maputo City Citywide Sanitation Planning

3.4. Treatment, disposal and reuse

This section provides an overview of sludge treatment, technologies, and decision criteria. This topic is broad and complex; we recommend the two following resources for more detailed work:

- Kevin Tayler's book Faecal sludge and Septage treatment for detailed design.
- The Guide to Sanitation Resource Recovery Products & Technologies to gauge which reuse products are appropriate and which treatment can produce them.

3.4.1. Disposal in trenches or sewers

The simplest and cheapest option can be to not treat faecal sludge, but instead to bury it. This can be a temporary measure until funding becomes available for proper treatment. The approval, planning and construction of a treatment plant can take years, during which such disposal will at least allow the removal of untreated sludge from human settlements.

Disposal in covered trenches (also known as **deep row entrenchment**), is suitable when there is available land, for instance for small towns and peripheral areas of larger cities, and when the risks of groundwater contamination and flooding are low. This land needs to be fenced and located away from housing, and requires some minimal management to ensure trucks do not damage the area during disposal. Freshly disposed sludge should be covered with soil to reduce smell. Trees are sometimes planted on top of the trenches.

The disposal of faecal sludge in sewers is usually not advised, unless there are specific processes such as additional settling tanks. It has been tried by some operators, so that sludge is carried to a wastewater treatment plant. Sewers are, however, not designed for these additional solids and may become clogged. Wastewater treatment plants are also not designed to cope with the increased solids, pathogenic load and organic load, reducing their efficiency or even preventing safe treatment. One alternative is to separate solids and liquids (see section 3.4.4), and to co-treat the liquid portion with wastewater. There is a comprehensive guide by Dorai Narayan on co-treatment.

3.4.2. Overview of treatment process

The simplest and cheapest option can be to not treat faecal sludge, but instead to bury it. This can be a temporary measure until funding becomes available for proper treatment.

The main objective of treatment is to convert faecal sludge into safe products that do not harm public health nor the environment when disposed of. A secondary objective is to use the energy and nutrients in sludge when it makes practical and economic sense to do so.

Faecal sludge cannot be treated in the same way as wastewater, as it is usually more concentrated. The simplest option, when the risk of contamination is low and space is available, is to bury the sludge in trenches and then cover the trenches with soil (section 3.4.1). However, a Faecal Sludge Treatment Plant (FSTP) is often required. The treatment process in an FSTP typically consists of:

- **Reception** and **screening** to remove larger solids, grit, fats, oil and grease (FOG), or floating objects, that could disrupt the treatment process.
- **Preliminary treatment:** stabilisation of fresh sludge, to reduce odours.
- **Separating solids and liquids**, to treat them separately and more efficiently.
- **Dewatering solids**, to remove excess water remaining in the sludge. Then:
    - **Transporting solids to a landfill,** or
    - **Further treating solids** to create products.
- **Treating liquids,** to remove the organic material, ammonia and pathogens. This is more like wastewater treatment, and liquids can be co-treated with wastewater. Then:
    - **Disposal in water bodies,** or
    - **Further pathogen removal** for irrigation.

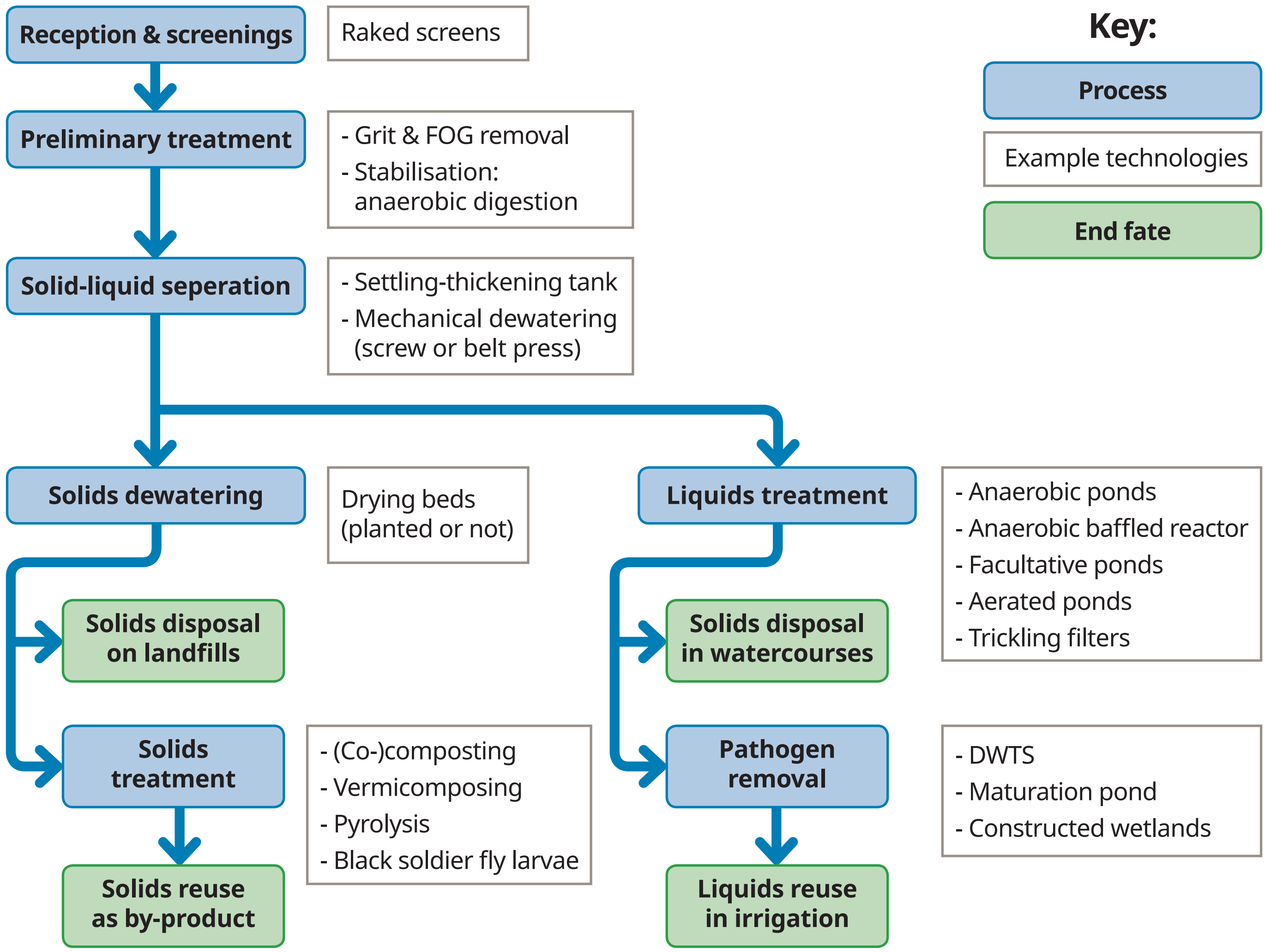


Figure 12: Typical processes in an FSTP, adapted from Faecal sludge and Septage treatment

Some of the products of faecal sludge treatment include:

- **Fertiliser / soil conditioner:** Used to enrich soil and improve crop production, but typically low value, especially where chemical fertilisers are subsidised. Human excreta alone tends to produce a lower-quality soil conditioner than when mixed with organic waste.
- **Biogas:** The gas generated by anaerobic digestion can be used for cooking or generating electricity. Anaerobic digestion also produces slurry, requiring treatment.
- **Biochar:** The residue of the burning of dried sludge can be used as a substitute for coal, as a soil conditioner or as material for water filters.
- **Black Soldier Fly (BSF) larvae and earthworms:** these animals grow by decomposing dried sludge and can be used as feed for animals.

3.4.3. Decision criteria for treatment options

Besides the overall FSM criteria listed above in section 3.1, the following factors should be considered when evaluating treatment options:

- **Volume and characteristics of the sludge:** Its quantity (current and future), seasonality, and composition: Biological and Chemical Oxygen Demand (BOD and COD), total suspended solids (TSS), viscosity, presence of larger solids, FOG, grit. Before beginning to design an FSTP it is essential to carry out a detailed assessment to determine the expected quantity and quality of the faecal sludge to be treated. The characteristics of the sludge will vary considerably depending on whether it is from pits or septic tanks, and how regularly they are emptied.
- **Level of treatment required:** This is governed by national standards, for instance the BOD and COD of the effluent, and international standards such as WHO guidelines. The installation of a treatment plant may also require an Environmental Impact Assessment.
- **Location and space available:** an FSTP can occupy a large area of land and generate unpleasant smells, the most common reasons for residents objecting to it.
- **Modular upgrading:** It may be possible to start small with essential components (like drying beds), and upgrade later as demand increases and more sludge arrives.
- **Operation and maintenance costs:** some processes can operate under gravity-flow while others will require mechanical equipment which will generally be more expensive to maintain and require a reliable source of electricity. Sometimes there is a trade-off – for example, mechanical dewatering will reduce the size of the drying beds and overall footprint of the FSTP but increase maintenance costs.
- **Political will:** The 'best' treatment process is sometimes the one that will get actual approval! This may be because the chosen option will:
  - bring jobs
  - be innovative and bring visibility,
  - be almost invisible and cheaper to run,
  - not produce unpleasant smells
- **Demand for FS products.** A market assessment can determine whether the products are worth it. Is there existing demand and willingness to pay, such as agriculture (for compost), kitchens nearby (for biogas)? Will the product have competition (for instance chemical fertiliser)?
- **Human resources:** Available skills and required staff to operate and maintain the FSTP, and level of protection required for their health and safety. Some technologies demand specialised expertise (like BSF larvae).
- **Available funding:** Funding is also important to determine treatment options. The sale of products usually covers only a small proportion of the total operational costs; the revenue should be compared with the investment. The REVAMP tool helps to gauge potential value.

3.4.4. Solid-liquid separation

A **settling-thickening tank** is a simple tank which thickens the sludge by separating the solids from the liquids over time. Some solids are pulled by gravity to the bottom, and some solids (e.g., FOG) float at the top, forming a scum layer.

The more liquid portion in the middle is called supernatant; it has the characteristics of domestic wastewater and can be treated with conventional wastewater treatment technologies. Solids can then go to an anaerobic digestor to produce biogas, or to further dewatering and treatment technologies.

Settling-thickening tanks are better suited to treat partially stabilised sludge such as septage from septic tanks or most other onsite sanitation facilities. It is not adapted for very fresh sludge, such as from public toilets, although this sludge can theoretically be mixed with better stabilised sludge from older pits.

While these tanks are simple to operate, they require regular cleaning of outlets, and some pumping of the sludge at the bottom. The main alternatives are: **mechanical dewatering**, which requires more investment, electricity and maintenance; or co-treatment with wastewater in **waste stabilisation ponds**, which require large areas of land.

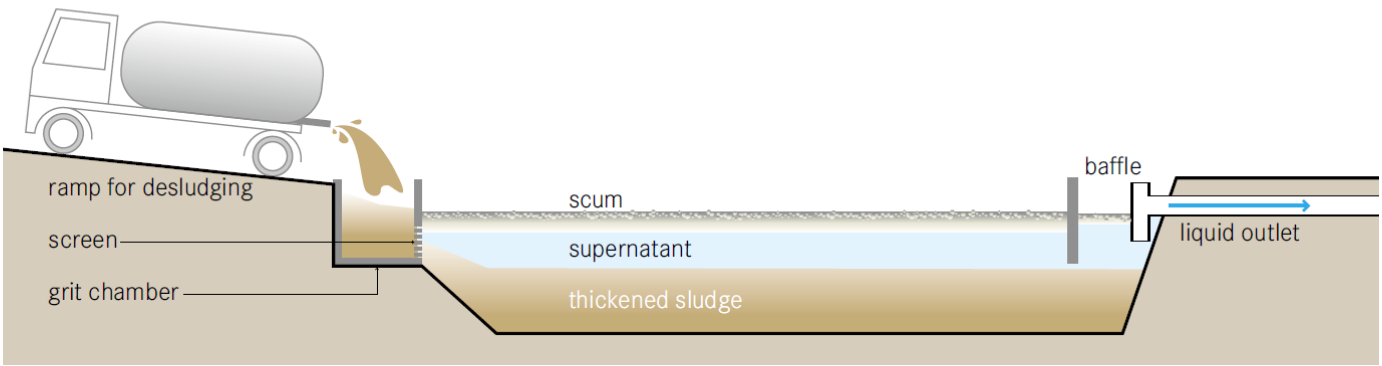


Figure 13: View of a settling-thickening tank © EAWAG (source)

3.4.5. Solids dewatering: drying beds

An **unplanted drying bed** is a simple bed filled with filter material, often gravel and sand, which allows the liquid from the faecal sludge to drain and evaporate, drying the faecal sludge. 50 to 80% of the volume of sludge percolates as liquid. The sludge accumulated on the beds is scraped regularly. This dried sludge is not yet effectively stabilised or safe. Additional treatment is usually required before it can be safely disposed or reused. The liquid portion or percolate still contains pathogens and needs further treatment.

Unplanted drying beds are usually one of the first (and sometimes only) technology installed at an FSTP: they provide effective treatment with minimal operation, they do not necessarily need a settling-thickening tank, and can provide a steppingstone towards more advanced treatment.

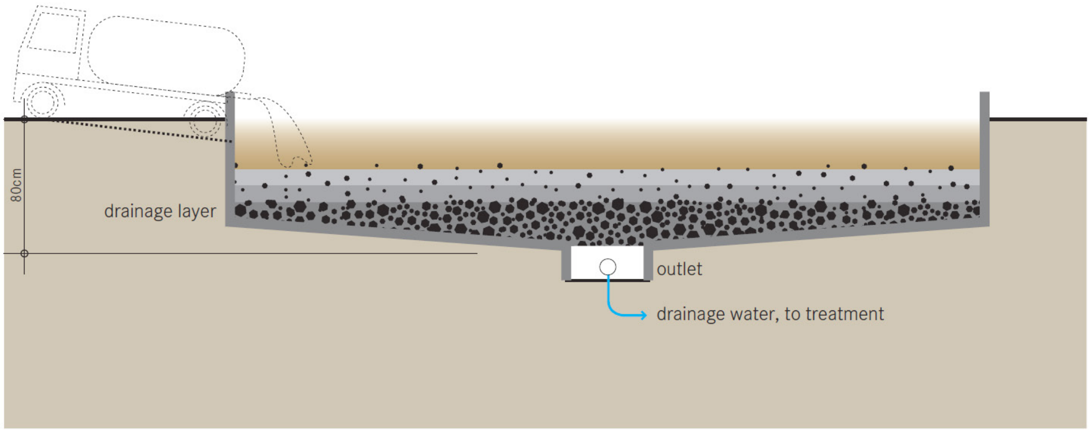


Figure 14: Diagram of an unplanted drying bed, CC-BY EAWAG

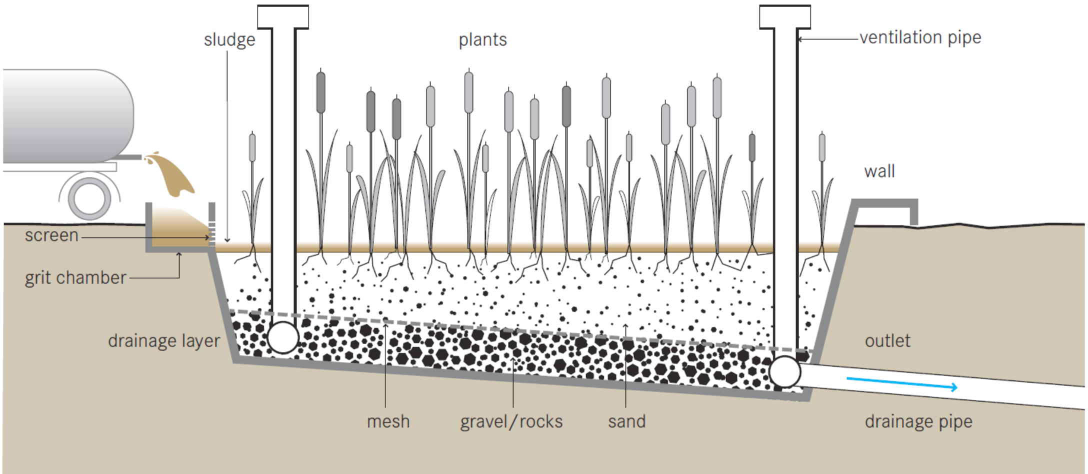


Figure 15: Diagram of a planted drying bed, CC-BY EAWAG

A **planted drying bed** is similar to an unplanted drying bed with the advantage of increased evapotranspiration by selected plants. Raw sludge can be applied directly to the previous layer or after pre-treatment in settling-thickening tank. Plants and their roots maintain the permeability of the filter. The accumulated sludge is removed every 2 to 5 years and has an advanced degree of stabilisation. The sludge does not require any other treatment step and can be used for crop production.

While they provide better treatment, they also require more expertise to choose the right plants for the climate, and maintenance for the plants and the handling of dried sludge.

3.4.6. Anaerobic digestion: biogas reactor

Anaerobic digestion, usually using **biogas reactors**, is a process which reduces the mass of faecal sludge by around 35 to 40% through biological degradation in an environment without oxygen, to stabilise organic matter and reduce smells; it produces biogas, a mixture of mostly methane and carbon dioxide, and a compact residue called slurry or digestate.

The biogas can be used for:

- **Electricity production:** an attached power plant burns biogas to produce electricity.
- **Purification and sale:** the methane is extracted and compressed for resale.
- **Combustion and treatment:** a boiler burns the gas for sludge thermal drying, improving the treatment process.

These options can generate significant income but require large capital investments, and installations of a sufficient size: it is possible to install domestic biogas reactors linked to household or small community toilets, but their gas production is mostly for home cooking and isn't usually commercially viable. As reactors significantly reduce the mass of sludge, they are also an interesting step before further treatment.

Biogas reactors require good expertise for installation and operation, to ensure safety when dealing with a flammable gas. They are also not very suitable for septic tank septage which, due to its long residence time, has lost its ability to produce methane.

Figure 16: Safisana's biogas plant in Ashaiman, Ghana © Safisana

3.4.7. Aerobic digestion: composting

Aerobic digestion usually refers to **composting:** when dried sludge decomposes in the presence of oxygen, and becomes similar to soil. The resulting product can be used as soil conditioner (lower value) or as fertiliser (higher value), depending on the quality of the treatment process. Turning large amounts of sludge into compost requires monitoring of temperature and humidity, and ensuring ventilation by turning the pile of materials regularly.

Dried sludge can also be mixed with organic waste, a process known as **co-composting.** To achieve this, solid waste should ideally be separated at the source (requiring behaviour change), as separation of mixed waste is expensive. The process requires the correct ratio of faecal sludge and organic waste, along with a bulking agent such as sawdust or rice husks.

Case study 8:

Co-composting plant in Sakhipur, Bangladesh

WaterAid Bangladesh has supported the town of Sakhipur to develop a town-wide sanitation solution, including small Vacutug tanker trucks and the development of a co-composting plant. The plant receives faecal sludge, dries it on drying beds, and mixes it with organic waste to produce compost, and then sold to local farmers. The liquid portion is treated in a decentralised wastewater treatment plant. See more in a short learning brief and through a virtual visit.

3.4.8. Liquids treatment

The liquid portion or effluent is still harmful and needs to be treated. It can be treated using conventional wastewater treatment, such as activated sludge (used by most wastewater treatment plants) and waste stabilisation ponds (which require no electricity but require large areas of land). One example resource is the Degremont Water Handbook.

Main principles

The main objectives are to reduce the organic load and suspended solids load, and possibly some of the nutrients such as nitrogen and phosphorous, which can be harmful to life in watercourses. Most countries have discharge standards for effluent organic and suspended solids concentration, expressed in BOD_5, COD and/or TSS. There are also WHO guidelines for reusing treated wastewater for irrigation. A difference with sewerage wastewater is that the BOD, COD, and ammonia concentrations in faecal sludge and septage are much higher.

There is a range of options, generally in this order:

1. **Anaerobic treatment,** which does not need power and works well on high-strength effluent coming from faecal sludge. It is used to reduce the demand placed on aerobic treatment afterwards. It can be done with anaerobic ponds (deep ponds) or anaerobic baffled reactors (tanks with several compartments).
2. **Aerobic treatment,** to reduce organic content and meet required discharge standards. It can be done with facultative ponds (shallower ponds), constructed wetlands (where plant roots help oxygen circulation), or mechanically aerated options, which use less land but need power and more maintenance.

3. **Pathogen reduction and polishing** if required, for instance for irrigation, or if the discharge will happen in a watercourse used for bathing or drinking. This can be done with maturation ponds (which need a large land area), or more complex options such as treatment with chlorine, ozone or ultraviolet radiation.

Decentralised Wastewater Treatment System (DWTS)

DWTS are small treatment stations designed to treat wastewater and the liquids from faecal sludge. They are an alternative to large centralised plants. A DWTS can be compact, relatively cheap to install, and require little maintenance and no energy input. This treatment option can be appropriate for a cluster of households and institutions (e.g., schools, health centres).

A DWTS typically consists of several elements: a settling tank (e.g., septic tank, sedimentation pond), an anaerobic baffled reactor, an anaerobic filter, and a series of constructed wetlands. When used to treat the liquid portion of faecal sludge, the septic tank can be omitted. The exact dimensions and types of installations depend on many parameters, which are covered in WaterAid's technical guidelines on DWTS.

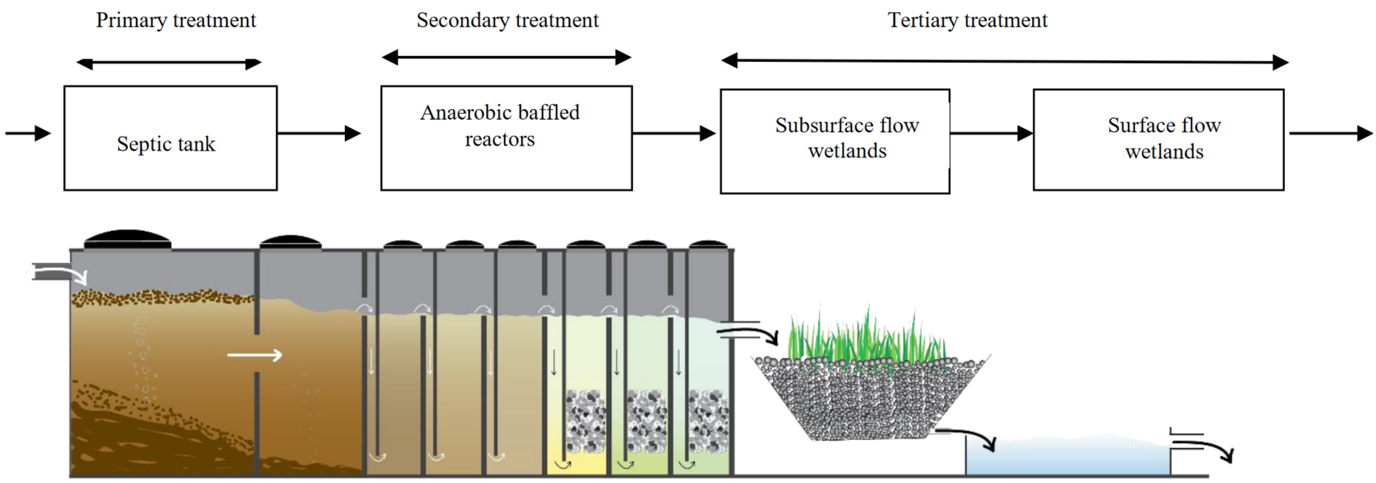


Figure 17: DWTS schematic © WaterAid / Abdullah Al-Muyeed

3.4.9. Emerging technologies: BSF, pyrolysis

Some emerging treatment processes are worth studying when they make economic sense in some circumstances. The new treatment options are under active development and are promoted by a few private companies, and have yet to gain recognition and acceptance. They also require significant expertise, and usually a high level of initial investment. For more details, refer to the Guide to Sanitation Resource Recovery Products & Technologies.

Pyrolysis

Pyrolysis or carbonisation refers to the burning of dried sludge at temperatures above 200°C and little to no oxygen. It is a fast process, taking only a few hours, which destroys pathogens. It produces biochar or bio-charcoal, which can be used as a soil conditioner, for water filters, or a substitute for charcoal when cooking or heating. The process is complex to maintain and needs good filtration of exhaust gases to avoid pollution and smells.

Black Soldier Fly (BSF) larvae

This process relies on the larvae of the fly species Hermetia illucens. These larvae feed on decaying organic material, such as dried sludge, then move away from it for pupation and can be harvested, usually as a source of protein in animal feed, replacing other sources such as fish, and providing a high-value product.

The process requires a specific environment (temperature between 29 and 31°C, humidity 50 to 70%...), long processing times, and trained personnel, thus limiting its application so far to a handful of companies with the required expertise.

Case study 9:

SNV experiences

SNV has published interesting FS treatment experiences, including conventional treatment, fuel briquettes, BSF larvae, decentralised wastewater treatment, biogas production and deep row trenches.

4. Institutional, management and financial aspects

Ensuring safely managed sanitation for all is an immense challenge: the global cost of reaching SDG 6.2 for sanitation was estimated in 2018 at $20 billion per year for basic sanitation alone, and $50 billion for safely managed sanitation – more than four times the existing investments. There are many underlying causes, including low political prioritisation, inadequate financing, limited capacity, weak institutional arrangements and unclear roles and responsibilities. These are all weaknesses in WASH systems (see figure below).

This section considers what needs to be in place to deliver inclusive and sustainable FSM services, by considering:

1. The **cost** of such services, and possible **income** sources.
2. How these financial flows can work in practical **business models.**
3. How institutional roles, responsibilities and governance arrangements are defined in **management models, institutional arrangements** and **regulatory frameworks.**
4. Some prerequisites for action, such as **building political prioritisation,** good **planning** and subsequent **monitoring,** and WaterAid's roles in these.

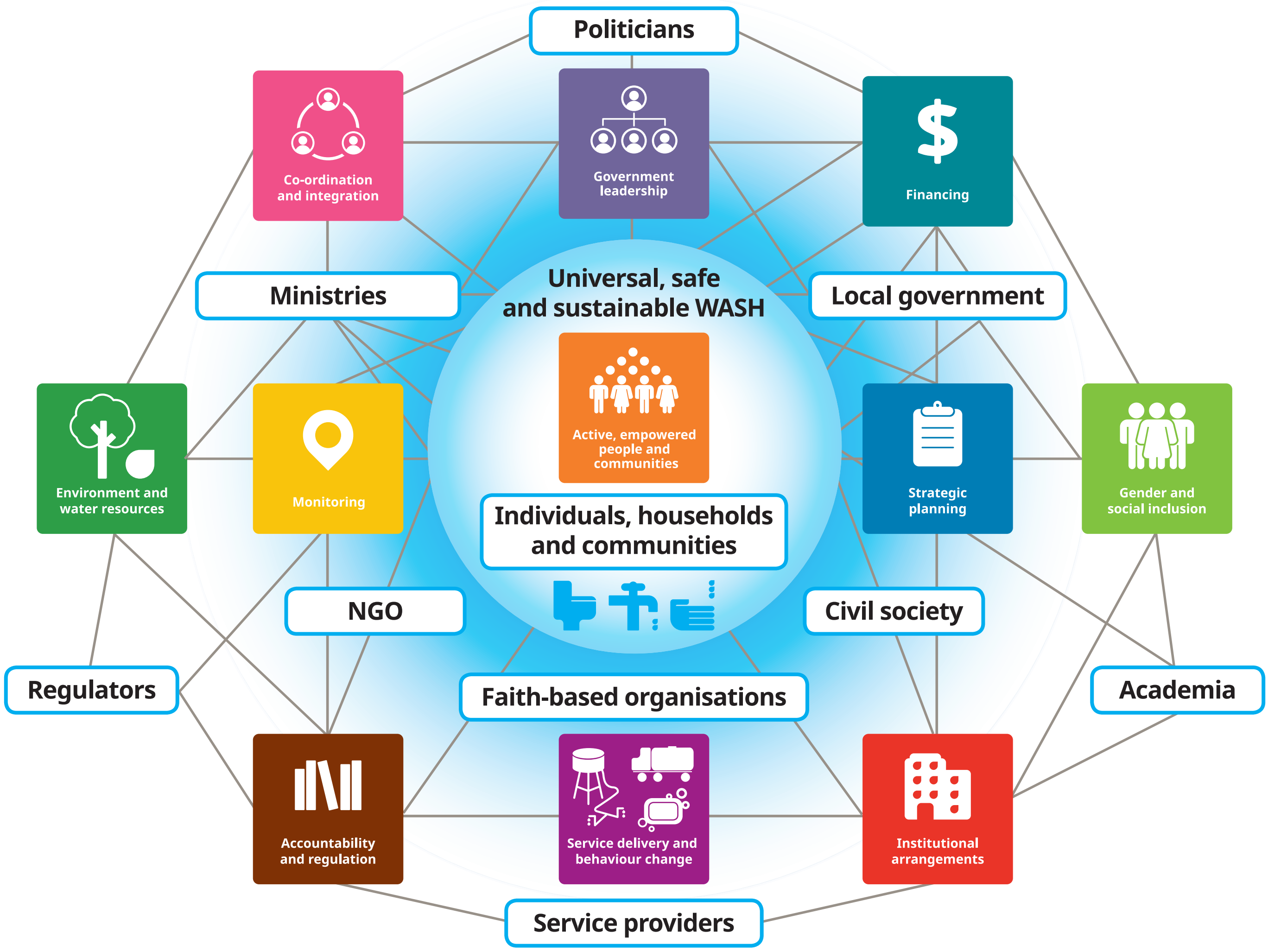


Figure 18: WaterAid's conceptualisation of the WASH system

4.1. Financing

4.1.1. Expenditure

The choice of the FSM chain is affected by the short- and long-term costs. It is important to understand the long-term cost of different approaches / solutions to assess if the business model and financing sources cover the costs. The cost of an FSM initiative can be assessed using the lifecycle costing methodology, which breaks down expenditure into the following components, applicable for both technologies and services:

- **Capital expenditure (CapEx)** such as buying emptying trucks and equipment, and building treatment plants; but also initial design, training and consultation costs.
- **Capital maintenance expenditure (CapManEx)** to renew or replace assets, depending on their expected life. This is often the most neglected component, which leads to non-functional services (e.g. truck breaking down).

- **Operational expenditure (OpEx)** including running costs of plants and vehicles (fuel, energy, protective equipment, chemicals...), routine maintenance, staff wages, etc.
- **Direct support costs,** including technical support, ongoing monitoring, licensing, etc.
- **Indirect support costs,** such as policymaking, regulation, reporting, etc.

These headings can also include **subsidies** needed to make sure everybody can have affordable and equitable access to services, for example vouchers for emptying services, rebates on bills, etc.

To assess such costs, the World Bank has developed a CWIS costing tool which compares various chains; the CACTUS research project also compares the costs of many chains.

See also: WaterAid's guidance on lifecycle costing for rural sanitation services

Case study 10:

Comparing the costs of sewerage and FSM

A 2012 study focused on Dakar, where both sewerage and FSM coexist, and annualised both capital and operating costs. It showed a familiar trend: FSM costs are about 5 times less than sewerage, but households pay almost 5 times more for FSM services, and utilities almost 30 times less. This situation is often due to the way sanitation is subsidised: new sewer installation and its maintenance / replacement is often paid by central government funding, and these costs are often not included in what should be covered by customers' bills. With on-site sanitation systems, there is often the (unrealistic) expectation that most of the costs should be recovered from fees at local level.

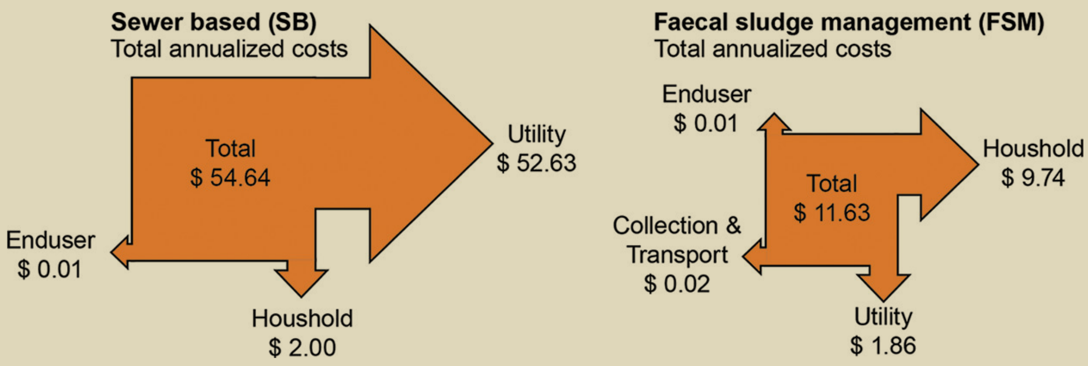


Figure 19: Comparison of overall costs and who pays for them © ACS

4.1.2. Income

Typical financing streams related to FSM include:

- Tariffs:
  - **Surcharges on water bills,** commonly used for sewerage as water use is often commensurate with wastewater production; e.g. Maputo, Ga West.
  - **Collection / emptying fees** for emptying pits and septic tanks, usually charged to residents directly, possibly including subsidies, e.g. Kampala.
  - **Licensing fees,** paid by emptying, transport and treatment businesses allowed to operate.
  - **Disposal fees** for discharging sludge at treatment plants, usually paid by emptiers and factored in their emptying fees.
  - **Sales** of reuse products e.g., compost, biochar, electricity from biogas.
- **Taxes,** and especially local property taxes, e.g., in Ghana.
- **Transfers** from central government and development partners.

Beyond this simple breakdown, the allocation of income streams for specific cost components can vary widely, depending on management models and regulation. For instance, utilities are often expected to recover operational costs from tariffs, but large-scale capital investments are more often paid by transfers; these in turn can be provided by development banks in the form of loans. While WASH financing is beyond the scope of this guide, WSUP and ESAWAS have published a useful paper on urban sanitation resourcing and financing.

See also WaterAid's study of municipal finance for urban sanitation in South Asia

4.2. Business models

To ensure safely managed sanitation is sustainable, both capital and recurring expenditure must be covered. The different ways to organise these financial flows and associated activities forms a **business model,** whether performed by a public or private institution.

A key resource is Business models for FSM which details some existing business models, using the Business Model Canvas. The Canvas is a standard template, which starts with the value proposition (the main ways to generate value to people) and considers who are the main customers and how to reach them, what are the main activities who are the stakeholders, and therefore what will be the costs and income streams.

The analysis from this resource shows that some elements of the sanitation chain can be profitable, such as emptying pits or selling derived products; but the whole chain tends to be loss-making in the absence of subsidies. Therefore, even if some aspects are delegated to private actors, public intervention is still necessary to ensure safe management.

Below is a generic model, showing four possible colour-coded value propositions. Text without colour stands for all value propositions.

Key partners	Key activities	Value propositions	Customer relationships	Customer segments
Municipality & local authorities Technology suppliers Financial institutions Community-based organizations R&D institutions (e.g., local university)	FS collection and transport	VP1: Safe emptying and transportation of FS	Service provision Contract from municipality	Residents Businesses Municipality
	FS treatment (drying and disposal)	VP2: Treating FS for safe disposal	Licence to operate and contract with performance targets	Municipality
	Organic waste and FS collection Co-compost production Compost sale & marketing	VP3: Producing high quality compost (soil ameliorant)	Distributors Direct compost sale	Farmers Municipal parks department Agriculture department Agroforestry Fertiliser industry
	Biogas production Electricity sale Customer relationships	VP4: Reliable and renewable energy service	Power purchase agreement	Residents Small businesses Grid
	Key resources		**Channels**	
	Technology, equipment Labour Finance License and contracts for collecting waste		Direct Municipality Word-of-mouth Brochures / media Distributors	

Cost structure	Revenue streams
Capital cost (construction, trucks, equipment, etc.) Operation and maintenance cost (labour, raw materials, utilities, sales and marketing, license, etc.) Interest payments	Emptying fees, monthly contracts FS disposal fees, sanitation tax, O&M budget support Sale of compost Sale of energy

Figure 20: A generic business model canvas for FSM, based on this guide.
Unshaded text applies to all value propositions.

The following page represents some common elements of business models, shown along the sanitation chain, along with the flow of products (red) and finance (blue), and some example relationships (green).

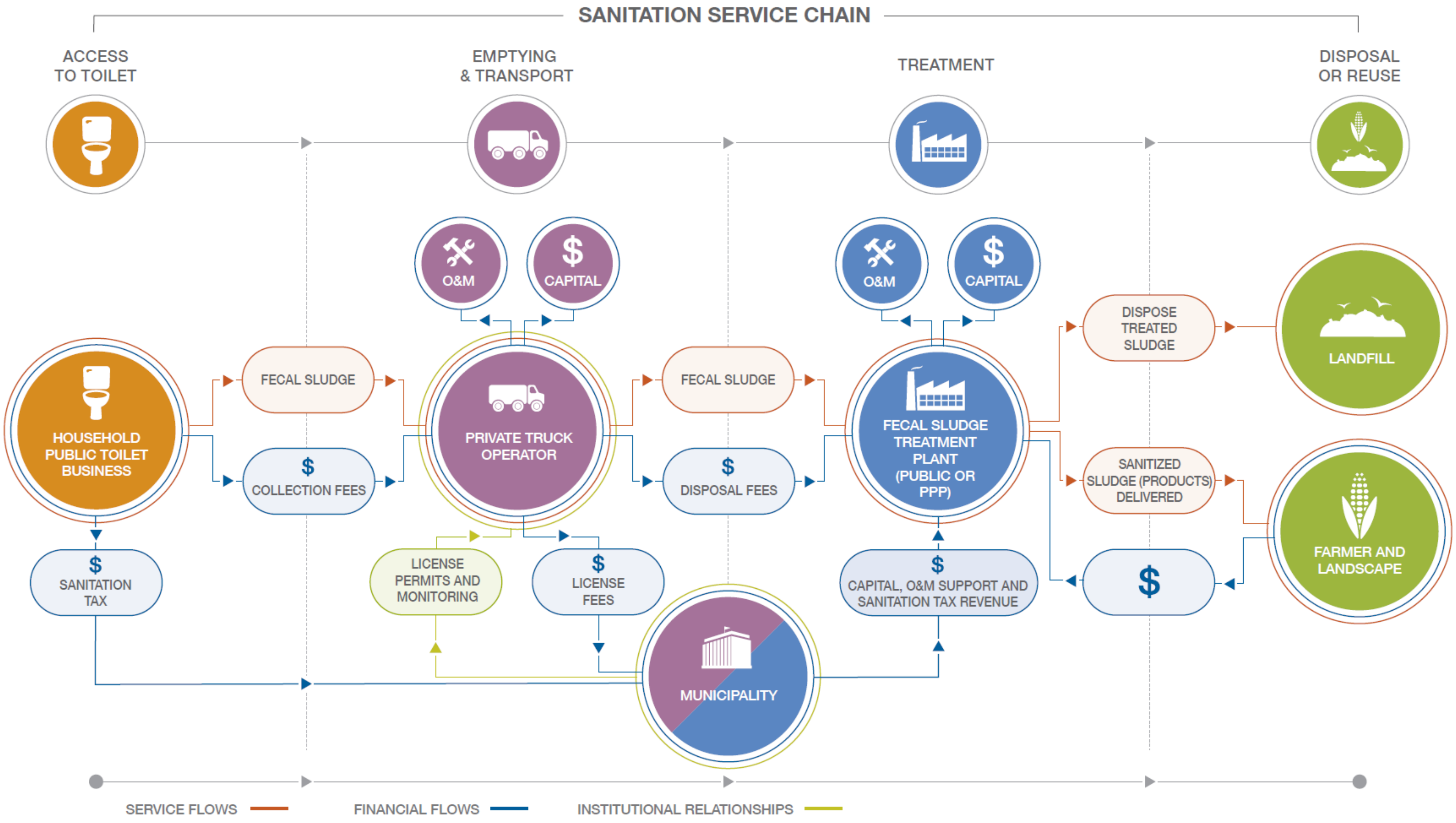


Figure 21: Common elements in business models for FSM © CGIAR / IMWI

4.3. Management models

Management models define the roles and responsibilities of the different actors involved in the sanitation chains. WaterAid has already studied management models for piped water supply, looking at the different stakeholders responsible for policies, service delivery, regulation, monitoring, accountability, etc.; it is an extensive topic, dependent on the socio-demographic profile, existing practices, customs and governance. Therefore, there is no single "right" model.

In Southern Africa, we have also studied management models for sanitation report expected to be published soon. Below is a diagram providing an overview of the different management models observed:

	Household management	Local government	Large utility	Private operators	
Management model	**Households manage their toilet with little to no external support.**	**Local government directly performs functions across the chain**	**Large public or corporatized utility performs functions across the chain**	**Informal operators empty, indiscriminate dumping**	**Formal operators for emptying and transport**
Regulation & oversight	Building and housing standards	Ministry or informal self-regulation	Independent regulator or ministry	Sometimes licensing by local government	Local government oversight, licensing
Toilet & containment	Households build and maintain. Private suppliers used for building, digging, supplying materials. Tenants are dependent on property owners				
Emptying & transport	Household (cover and move)	Local government	Public utility (e.g., operation of large plants and truck fleet)	Informal operators (small pumps)	Formal private operator (trucks)
Treatment, reuse, disposal	Household (ecosan compost reuse)			Varies	Local government or public utility

Table 2: Example management models for sanitation in Southern Africa

4.3.1. Typical management models

Some of the main sanitation management models include:

Household management

This applies to toilets which do not need emptying services, such as toilets with in-situ treatment (section 3.2.3: twin pits, ecosan...) and when pits can be safely covered when full, most common in rural areas. Regulation often exists in building and housing codes.

Public management

In this case, the government manages the entire FSM chain from collection to treatment and reuse through public stakeholders like municipalities or public utilities, which may operate at the national or sub-national level.

Case study 11:

Malaysia: Scheduled emptying

Malaysia developed a vision of a "sanitation dream" in the 1990s: water access was improving dramatically, creating more wastewater to treat and pollution in rivers. Authorities created in 1993 the Indah Water Consortium (IWK) to take charge of sanitation service delivery at the country level, including FSM. IWK's actions have included:

- Developing a standardised septic tank, which however did not increase demand for emptying.
- Creating a "scheduled emptying" mechanism, whereby all septic tanks are emptied every two years. This was financed by a water surcharge as part of the local tax.
- Installing better treatment plants with gradual increases in capacity.
- Creating an independent regulatory body to ensure public targets are met.

Public-private partnerships (PPPs)

Some of the FSM services can be fulfilled by private operators, with a wide variety of contractual arrangements. The table below, adapted from the Asian Development Banks' PPP handbook, compares some typical PPPs used in sanitation:

Type of PPP	Service contract	Delegated management	Lease Contract / affermage	Concession	Build-Operate-Transfer
Scope	Contracting out many support services (meter reading, billing, etc.)	Delegating to a private provider the management of all operations or a major component	Contracting a private provider for management, operations, and specific renewals	Private provider is responsible for all operations and for specific investments	Investment in / operation of a major component e.g., treatment plant
Duration	1-3 years	2-5 years	10-15 years	25-30 years	Varies
Asset ownership	Public	Public	Public	Public / Private	Private / Public
O&M responsibility	Public	Private	Private	Private	Private
Commercial risk	Public	Public	Shared	Private	Private
Finances:					
Capital investment	Public	Public	Public	Private	Private
Maintenance investments	Public	Public / Private	Varies	Private	Private
Compensation terms	Unit prices	Fixed fee with performance incentives	Portion of tariff	All or part of tariff revenue	Mostly fixed
Competition	Intense and ongoing	One time only; contracts not usually renewed	Initial contract only; subsequent contracts usually negotiated	Initial contract only; subsequent contracts usually negotiated	One time only; often negotiated without direct competition
Examples		Kumasi, Naivasha	Many wastewater treatment plants	Dakar FSTPs	

Table 3: Comparison of typical PPPs used in sanitation

One rule, as noted in WaterAid's review of the functionality of wastewater treatment plants, is that private sector operation is only as effective as the public sector's capacity to regulate. Good regulation, monitoring, accountability and enforcement allows tracking the performance of private contractors against criteria of affordability, equity, sustainability and transparency.

If the capacity of public institutions is weak, they are often unable to provide services, and small entrepreneurs informally fulfil this role. This is often the case with emptying services. In this case, it is useful to build an enabling environment, such as the gradual development of regulation so that these businesses can expand and provide reliable and affordable services. Water for People published a guide on how to create such an enabling environment; WSUP has documented this management model in Kisumu.

Case study 12:

Dakar: Structuring the sludge tankers' market

In Dakar, Senegal, the volume of faecal sludge was increasing, and emptying services could not keep up with the demand. Manual desludging was unsafe, and mechanical emptying was done with ageing trucks which would often break down. The Senegalese National Sanitation Office (ONAS) began to focus increasingly on on-site sanitation. Since 2006, ONAS has installed several treatment plants and improved the regulation of the emptying market, where prices were often inflated. They created a customer call centre to distribute demand for emptying services, control prices and use a guarantee fund to allow private desludgers to upgrade their trucks. They involved emptiers in testing innovative technologies, such as the Omni-processor, and in elevating their profile in national media.

4.3.2. Regulatory framework

A national regulatory framework is important for the following reasons:

- Definition of roles and responsibilities of the different stakeholders along the sanitation chain, including FSM.
- Description of a vision for sanitation, with CWIS (section 2.3.1) as guiding principles.
- Description of the strategic and planning processes to achieve this vision.
- Identification of the possible service options, technologies and standards.
- Description of the financing arrangements.
- Explanation on accountability and how progress and performance will be monitored, for instance:
    - Coverage targets
    - Quality and safety standards, including Standard Operating Procedures (SOPs)
    - Mechanisms set up to serve the most excluded
    - Incentives for services providers to expand coverage
    - Sanctions for poor performance or non-compliance
    - Price regulation mechanisms
    - Integration of informal service providers
    - Responsiveness to the diverse demographic / social needs of the population.

ESAWAS has several excellent publications to inform regulatory frameworks for sanitation.

Several countries have developed such frameworks, often in collaboration with civil society, development partners and academia:

Case study 13:

Zambia On-site sanitation regulatory framework

In 2016, following national commitments and support from funders, the National Water and Sanitation Council (NWASCO) in Zambia saw its mandate extended beyond urban sewerage to rural sanitation and on-site sanitation. It formulated a national FSM framework by consulting authorities, utilities, NGOs and main private sector actors. The framework clarified roles and responsibilities, and offered several management models for public and private utilities. NWASCO then worked on defining licensing guides, pricing strategies, capacity assessments, etc.

NWASCO identified lessons learnt through this process: Key areas included clarifying roles of various agencies, and defining which standards and regulations apply; the process relied heavily on previous data and surveys, and on the engagement with a wide variety of organisations.

Case study 14:

FSM Framework in Bangladesh

Bangladesh has become open-defecation free and is now tackling the “second generation” challenge of safely managed sanitation, particularly through FSM. In 2017, the government of Bangladesh developed a regulatory framework for FSM, after consultations with local authorities. The framework is divided according to geographies: Dhaka, city corporations, pourashavas (smaller municipalities), and rural areas. It clarified the responsibility for FSM by placing it explicitly on local government, with technical support from a central agency.

This was accompanied by a dissemination programme led by the International Training Network of the Bangladesh University of Engineering and Technology, to train staff in target institutions and build local leadership. FSM action plans have been developed depending on local situations and appropriate technologies.

4.4. Political prioritisation

This section considers the processes that can help lead to improvements in FSM. Sanitation progress is off-track against the SDGs because it is often not prioritised, compared to other infrastructure and public investments. FSM is often seen as a temporary solution until sewerage can be installed, and perceptions need to change.

Case study 15:

A tale of clean cities: drivers of progress

This study considered how sanitation improved in San Fernando (Philippines), Visakhapatnam (India), and Kumasi (Ghana). Common drivers of progress were sanitation champions at the municipal level, national political influence, economic considerations, and support from development partners.

Progress resulted from emerging opportunities. City sanitation planning was not a key determinant, but planning exercises made meaningful contributions, such as forging an aspirational vision of a clean city. These positive contributions were diverse and dependent on the level of development of sanitation in the city. The research suggested sanitation development could be structured into three phases: piloting, consolidation and city-wide expansion. Approaches to city sanitation planning could be tailored to these phases and to political opportunities to maximise their contribution.

There is no single approach to build political will; WaterAid has tried several tactics such as:

- **Persistent working with civil society organisations and communities** to learn from their efforts and engage local officials, as in Sakhipur, Bangladesh.
- **Conducting assessments** (through SFDs and larger studies) to reveal the extent of poorly managed sanitation. This often leads to debates with authorities which help focus attention on actual issues; the results can also be picked up by the media.
- **Engaging in citywide planning** with authorities and experts (as in Lusaka, Kinshasa, Lagos and Maputo through a partnership with architects and planners).
- **Conducting pilots** to showcase possible technologies, business models and management models, as with pit emptiers in Dar es Salaam.
- **Supporting utility reform,** especially through specialist training and peer-to-peer exchanges, so that they can invest in sanitation and expand services to excluded areas.
- **Supporting sectoral reforms,** for instance through involvement in developing the FSM regulatory framework in Bangladesh.
- **Exchange visits** between cities and between countries, exposing officials and professionals to successful projects and favouring peer-to-peer learning.

Case study 16:

Building political will in Sakhipur, Bangladesh

WaterAid Bangladesh helped build a co-composting plant in the small town of Sakhipur, Bangladesh. The mayor has become a sanitation champion, advocating strongly for FSM and for solutions such as those in Sakhipur. He mentions his visits overseas as his inspiration for having a clean and environmental town. He has hosted learning visits and has become a helpful ally to develop country-wide FSM. In short, he is the ideal municipal sanitation champion we should try to have. The work done behind the scenes by WaterAid and local NGO BASA since 2012 also helped to foster this leadership. This work has included:

- Travelling to other locations with the Mayor and municipal staff to "plant ideas"
- WaterAid funding some elements of the sanitation chain upfront, as an investment towards eventual municipal ownership

The mayor's support was important to obtain land for the plant, a persistent blockage– especially as residents objected to the plant being built near them, notably because of concerns about smell. Yet even with a willing municipality, it took two years to obtain land. More details in a learning note.

5. Useful resources

5.1. Key resources

- IWA & EAWAG, Faecal Sludge Management - Systems Approach for Implementation and Operation, 2014: also known as "the FSM book", it is a comprehensive guide to FSM, covering technical, institutional and programmatic aspects.
- WHO, Guidelines on sanitation and health, 2018.
- WSUP, Urban programming guide, 2014: an overview guide to see how FSM fits in wider urban work

5.2. Technical resources

- EAWAG, Compendium of Sanitation Systems and Technologies, 2nd edition, 2014, accompanied by the online e-compendium: a handy technical reference and points to more specialised documents.
- FSM Alliance, A Practical Guide to Available Pit-Emptying Technologies, 2022
- Kevin Tayler, Faecal sludge and septage treatment: a guide for low- and middle-income countries, 2018: Written by a renowned expert, this guide is excellent for detailed technical design of treatment
- Guide to Sanitation Resource Recovery Products & Technologies, 2021: an excellent resource to gauge the variety of reuse products, how mature they are, and which treatment technologies can produce them.
- CAWST, Faecal Sludge Management technical briefs, 2015

5.3. WaterAid resources

- Faecal sludge management landscape in South Asia, 2019
- Technical guidelines for designing a decentralised wastewater treatment system, 2017
- Comparison of urban sanitation tools and approaches, 2016
- A tale of clean cities: Insights for planning urban sanitation from Ghana, India and the Philippines, 2016
- Water Supply Service Options Feasibility Assessment: an internal tool to guide through the selection process, currently for water, but relevant for sanitation too.

5.4. Training courses

- Introduction to Faecal Sludge Management on Coursera: an 11-hour course covering the basics and focused on technologies
- Planning and Design of Sanitation Systems and Technologies on Coursera
- CAWST organises regular "introduction to Faecal Sludge Management" in-person training sessions – check their calendar.
- The CSE India offers training courses in onsite sanitation, some have been done for WaterAid staff.

Acronyms

BMGF	Bill and Melinda Gates Foundation
BOD	Biological Oxygen Demand (BOD_5: at five days)
BSF	Black Soldier Fly (larvae)
CACTUS	Climate And Costs in Urban Sanitation
CapEx	Capital Expenditure
CapManEx	Capital Maintenance Expenditure
CBO	Community-Based Organisation
CBS	Container-Based Sanitation
CBSA	Container-Based Sanitation Alliance
CLUES	Community-led Urban Environmental Sanitation Planning
COD	Chemical Oxygen Demand
CSE	Centre for Science and Environment (India)
CWIS	City-Wide Inclusive Sanitation
DWTS	Decentralised Wastewater Treatment System (also DEWATS)
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
ECAM	Energy Performance and Carbon Emissions Assessment and Monitoring
ESAWAS	Eastern and Southern Africa Water and Sanitation Regulators Association
FOG	Fats, Oils and Grease
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
IWK	Indah Water Consortium (Malaysia)
JMP	Joint Monitoring Programme
NWASCO	National Water Supply and Sanitation Council (Zambia regulator)
O&M	Operation and maintenance
ONAS	Office National de l’Assainissement du Sénégal
OpEx	Operational Expenditure
PPE	Personal Protection Equipment
PPP	Public-Private Partnership
SDG	Sustainable Development Goal
SFD	Shit-Flow Diagram / Faecal Waste Flow Diagram
SOP	Standard Operating Procedures
SSP	Sanitation Safety Plan
TSS	Total Suspended Solids
UDDT	Urine-Diverting Dry Toilet
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation
WSUP	Water and Sanitation for the Urban Poor

Index of figures, tables and case studies

Figures

Tables

Case studies

WaterAid/James Kiyimba

◀ Sanitation workers unfolding a long rubber pipe to reach a pit for emptying, Kigambon-Umawa, Dar es Salaam, Tanzania, June 2019

▼ Sanitation workers pour out the contents from emptying the pit in Bangalore, India. August 2019

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This guide and its translations can be found on washmatters.wateraid.org/fsm-guide

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WaterAid is an international not-for-profit, determined to make clean water, decent toilets and good hygiene normal for everyone, everywhere within a generation.

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