National Institute of Urban Affairs

Decentralized Wastewater Management

Complementing Centralized Solutions for Achieving 100% Sanitation Coverage

Learning Notes

TITLE:

DECENTRALIZED WASTEWATER MANAGEMENT: COMPLEMENTING CENTRALIZED SOLUTIONS FOR ACHIEVING 100% SANITATION COVERAGE – LEARNING NOTES

PUBLISHER:

NATIONAL INSTITUTE OF URBAN AFFAIRS, NEW DELHI

YEAR: 2019

CONTENT

The learning notes are prepared by compiling information sourced from various training modules prepared under Sanitation Capacity Building Platform (SCBP), an initiative of the National Institute of Urban Affairs (NIUA) for addressing sanitation challenges in India.

DISCLAIMER

While every effort has been made to ensure the correctness of data/information used in the training module, NIUA would not accept any legal liability for the accuracy or inferences drawn from the material contained therein or for any consequences arising from the use of this material. The module is for open use by public with appropriate citing to NIUA.

About this Handbook

This handbook is an initiative of NIUA to build capacities of urban local bodies (ULBs), para state technical agencies, administrators and professionals from the private sector and Non-governmental Organizations. It is meant to be freely used by any organisation (public or private), national and state level training institutes, AMRUT and SBM Training institutes: for conducting a two to two and a half day advance training on Decentralized Wastewater Management with focus on Faecal Sludge and Septage Management (FSSM) in Ganga Towns.

The Handbook presents the key learning elements for the advance training module in a narrative format covering the aspects of: urbanization and sanitation trend in India, wastewater management in ganga basin and challenges, sanitation systems, decentralised sanitation solutions for wastewater management – needs and challenges, decentralized wastewater and septage management technologies and best practices, planning and financing for citywide faecal sludge and septage management, policies and programs for wastewater management in urban areas. The training also involves exposure to best practices implemented on ground.

The Handbook has been developed based on the experience of delivering advance trainings on Integrated Wastewater and Septage Management (IWSM) and Faecal Sludge and Septage Management (FSSM) under the umbrella of Sanitation Capacity Building Platform (SCBP) anchored at NIUA.

About the Training Module

Title	Decentralized Wastewater Management: Complementing Centralized Solutions for Achieving 100% Sanitation Coverage Learning Notes
Purpose	The conventional approach adopted for managing wastewater and septage in urban areas is predominantly centralized, in the form of sewer networks and Sewage Treatment Plants (STPs). However, as per the 2011 census, only 38% urban households in India were connected to such centralized sewage systems, and only 37% of the sewage was actually treated (CPCB, 2015). In Ganga basin towns, only 10% of the sewage is treated and disposed as per standards. The rest finds its way into the rivers, drains, and water bodies. This has been widely attributed as the biggest source of pollution in the rivers of the Ganga Basin. A large part of urban households in ganga basin are not connected to any sewage system, and rely on septic tanks and other onsite sanitation systems. While these onsite systems are not really a concern, the improper disposal of the faecal sludge from such systems into water bodies and rivers causes the problem. It is increasingly becoming evident that only centralized solutions (especially in smaller towns) may not be sufficient to achieve 100% sanitation coverage. There is a need for cities to plan for both centralized and de-centralized options. Decentralized sanitation systems do not need extensive sewer networks. The fundamental feature of such systems is on collecting and treating the waste at source or as near as possible to source of generation. The waste streams (liquids and solids in wastewater) can be separately treated and require relatively simpler technologies for treatment. Faecal Sludge and Septage Management (FSSM) is one such decentralized approach of managing faecal matter that can complement sewerage systems in reducing pollution loads entering the river. While there has been significant focus on centralized sewer network solutions thus far, relatively less attention has been paid to decentralized solutions (especially FSSM) until recently. The planning for decentralized systems requires a different viewpoint in terms of policy and institutional framework, finances, technology, and stakeholder engagement. The capacities within parastatal organizations and urban local bodies in implementing these solutions are fairly limited. This training programme, therefore, seeks to plug this capacity gap by equipping concerned stakeholders with knowledge and skills to understand how to implement these decentralized solutions, with emphasis on FSSM. The significance of this training programme becomes even more pronounced in light of recent directions by central and state governments that mandate ULBs to promote decentralized sanitation.
Training module is for	Senior and mid-level technical officials (engineers) from ULBs (ganga towns) and Parastate agencies like Jal Nigam and technical staff from development authorities at district/ULB level, PMU/TSU staff supporting state government and cities in planning/implementing wastewater/faecal sludge and septage management interventions.

Learning Objectives	The central objective of the capacity building programme is to enhance the understanding of state and city officials on the role of decentralized sanitation systems in safe disposal of domestic wastewater and faecal sludge/septage generated in urban areas. The programme will have an emphasis on Faecal Sludge and Septage Management.
Learning Outcomes	By the end of the programme, it is envisaged that the participants will be able to: • Understand and appreciate the synergy between centralized sewer systems and decentralized wastewater treatment solutions including on-site sanitation. • Understand the role of State/ULB in planning/implementing decentralised sanitation solutions for effective wastewater management • Develop good working knowledge on various technology options for decentralised liquid waste management including FSSM. • Apply tools/techniques for planning decentralised wastewater management in urban areas • Make informed decisions and draw a broad action plan for 100% safe collection, conveyance, treatment and disposal of faecal matter in their respective ULBs
Duration	$2\frac{1}{2}$ days (two and a half days) **residential** training programme for approx. 25-30 participants.

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1 Urbanisation and Sanitation

1.1 Urbanisation in India

India is urbanizing but the pace and character of is different from countries in other parts of the world. In 2001, the numbers of Census towns and statutory towns were 1,362 and 3,799, respectively, while in 2011, these numbers grew to 3,894 and 4,041, respectively. The growth of population and urbanization has slowed down in the Million Plus cities in the last decade (2001-11), but continues to increase at a fast pace for smaller towns and cities. The number of urban agglomerations in the year 2001 was 384 and increased to 475[1] in 2011.

Table 1 - Number of UAs/Towns and Out Growths (OGs)

S. No.	Types of Towns	Number of Towns	
		Census 2011	Census 2001
1	Statutory towns	4,041	3,799
2	Census towns	3,894	1,362
3	Urban agglomeration	475	384
4	Out growths	981	962

Source: Census of India 2011

The total population of India increased from 102.86 crore in 2001 to 121.02 crore in 2011. The urban population in the year 2011 also increased to 37.71 crore from 28.61 crore in 2001. The percentage of urban population in the year 2001 was 27.8% which increased to 31.2% in 2011.

1.2 Urban sanitation and associated challenges

1.2.1 Urban Sanitation

"Sanitation is defined[2] as safe management of human excreta, including its safe confinement treatment, disposal and associated hygiene-related practices. Sanitation pertains to management of human excreta and associated public health and environmental impacts, it is recognized that integral solutions need to take account of other elements of environmental sanitation, i.e. solid waste management; generation of industrial and other specialized / hazardous wastes; drainage; as also the management of drinking water supply (National Urban Sanitation Policy, 2008).

<u>What is the definition of ODF/ODF+/ODF++ City?</u>

ODF – A city / ward can be notified / declared as ODF city or ODF ward if, at any point of the day, not a single person is found defecating in the open[3]. (Ministry of Housing and Urban Affairs, Government of India).

ODF+ – A city/ward can be notified/declared as ODF+ city or ODF+ ward if, at any point of the day, not a single person is found defecating and/or urinating in the open, AND all community and public toilets

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[1] Number of census towns and statutory towns are taken from http://censusindia.gov.in/2011-prov-results/paper2/data_files/India2/1.%20Data%20Highlight.pdf

[2] National Urban Sanitation Policy

[3] Ready-reckoner for "Declaring your City/Ward open defecation free" is available on http://sac.ap.gov.in/sac/UserInterface/Downlaods/IECMaterials/ODF%20Declaration%20booklet.pdf

are functional and well maintained. The cities that have been certified ODF atleast once on the basis of the ODF Protocol laid down by MOHUA shall be eligible to declare themselves as SBM ODF+ and apply for certification of SBM ODF+ status, as per the conditions laid down in this protocol document.

ODF++ - A city/ward can be notified/ declared as ODF++ city/ward if, at any point of the day, not a single person is found defecating and/ or urinating in the open, all community and public toilets are functional and well maintained, **AND faecal sludge/septage and sewage is safely managed and treated, with no discharging and/or dumping of untreated faecal sludge/septage and sewage in drains, water bodies or open areas**. The cities that have been certified SBM ODF+ atleast once on the basis of the SBM ODF+ Protocol laid down by MoHUA shall thereafter be eligible to declare themselves as SBM ODF++ and apply for certification of SBM ODF++ status, as per the conditions laid down in this protocol document.

1.3 Urban Wastewater Management

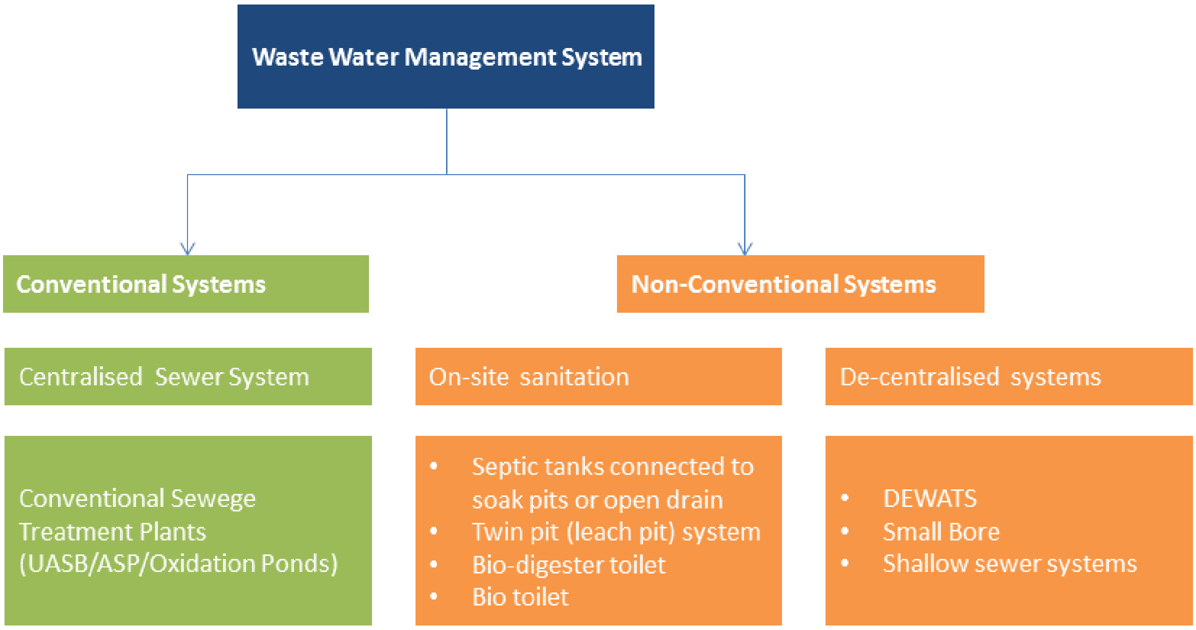


Figure 1 – Types of wastewater management systems

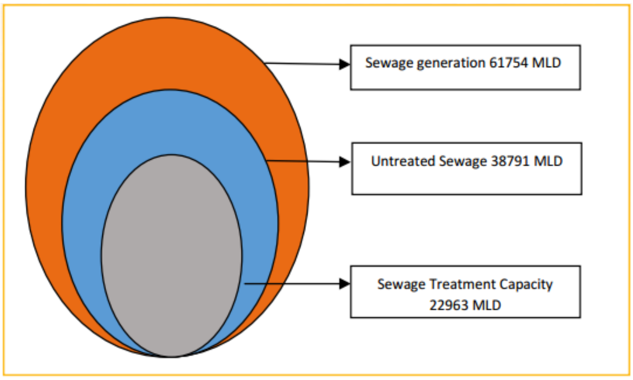
Providing safe wastewater conveyance and treatment systems in cities can be provided by broadly two approaches:

Wastewater management systems can be either conventional centralized sewer systems (also referred to as sewered sanitation) or non-conventional systems including on-site sanitation (also referred to as non-sewered sanitation) and decentralised systems. Centralized systems are usually planned, designed and operated by government agencies which collect and treat large volumes of wastewater for the entire communities. On the other hand, decentralized wastewater management (DWWM) systems treat wastewater of individual houses, apartment blocks or small communities close to their origin. Typically, the decentralized system is a combination of many technologies within a given geographical boundary, namely, onsite systems, low cost collection systems and dispersed siting of treatment facilities.

Wastewater treatment systems such as pit latrines, septic tanks, bio-toilet etc., which are used for partially treating wastewater in individual residences or a small cluster of houses, are termed as “On Site Sanitation Systems (OSS)” systems. OSS need not have any wastewater collection system, while a DWWM may have a small sewerage system. It may also be noted that any city or town can have a combination of centralized, decentralized and on-site wastewater management systems, to meet the overall city sanitation. (*Source – Guidelines for Decentralised Wastewater Management, prepared by IIT, Chennai for MoUD, GoI, December 2012*).

1.3.1 Centralised Wastewater Management (Sewered Sanitation)

In conventional wastewater management approach, centralised Sewage Treatment Plants (STPs) are set up and all wastewater generated is transported to STPs vis sewer lines. A centralized sewerage is perceived as an underground sewer system to collect the sewage from all over the settlement.



As per the 2011 census, only 38% urban households in India were connected to sewerage systems, where faecal waste is supposed to be conveyed to Sewage Treatment Plants (STPs). The estimated sewage generation in the country was 61,754 MLD and installed capacity for sewage treatment was only 22,963 MLD. However, the treatment utilization at these STPs is only 18,883 MLD (which means approx. only 30% of the total sewage that is generated gets treated). The rest is discharged into nearby water bodies (Central Pollution Control Board (CPCB), 2016). There are 920 STPs in different States/UTs out of which, 615 STPs are operational, 80 STPs are non-operational, 154 STPs are under construction and 71 STPs are under planning stage. (Source: CPCB, 2016).

<u>Wastewater Management in Ganga States</u>

There are 11 states in Ganga Basin with 5 being on main stem of the Ganga River. These states are Bihar, Uttar Pradesh, Uttarakhand, Jharkhand and West Bengal.

An analysis of Ganga basin town shows that only 10% of the sewage is treated and disposed as per standards. As much as 67% households are not connected to any sewerage system and the faecal waste from septic tanks is polluting the ground water, surface water bodies and Ganga river.

The wastewater generated in each ganga state and treatment capacities installed is mentioned in figure above. Across all the states, STPs installed are not adequate to treat volume of wastewater generated resulting in discharge of untreated flows entering water bodies like ponds/lakes and rivers. Bihar State has highest gap (94%) in terms of treatment capacity installed against quantum of wastewater generated. Uttar Pradesh has shortfall of 63% in treatment capacities.

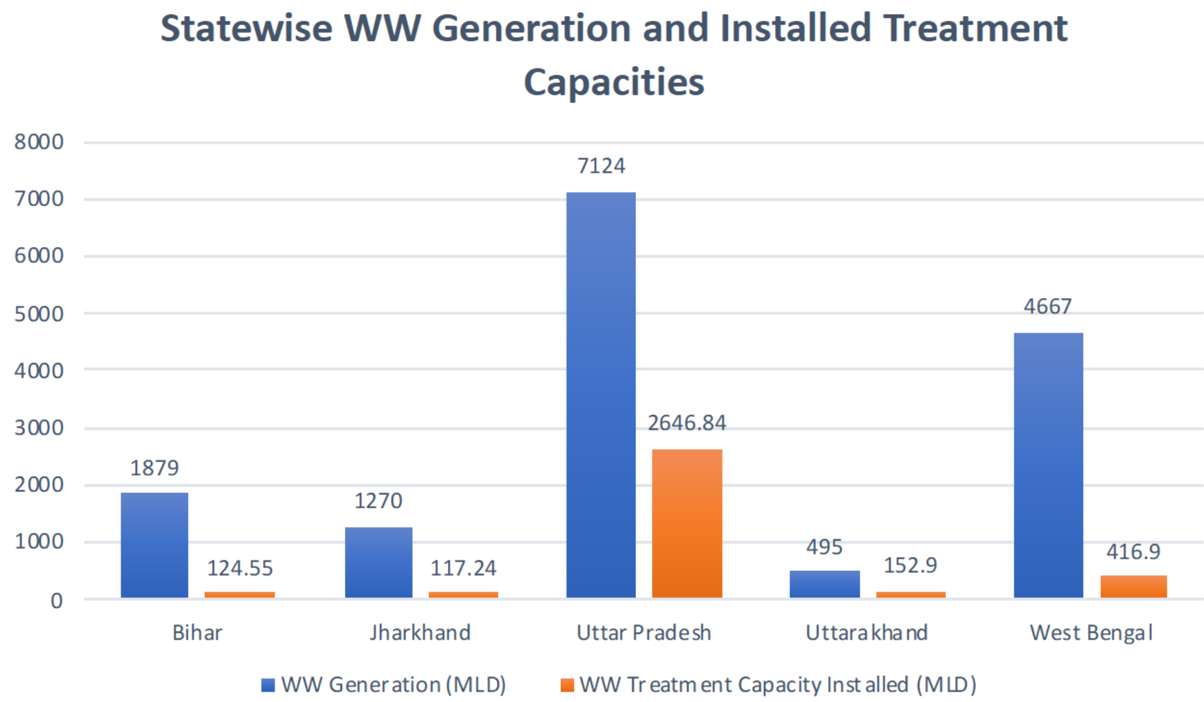
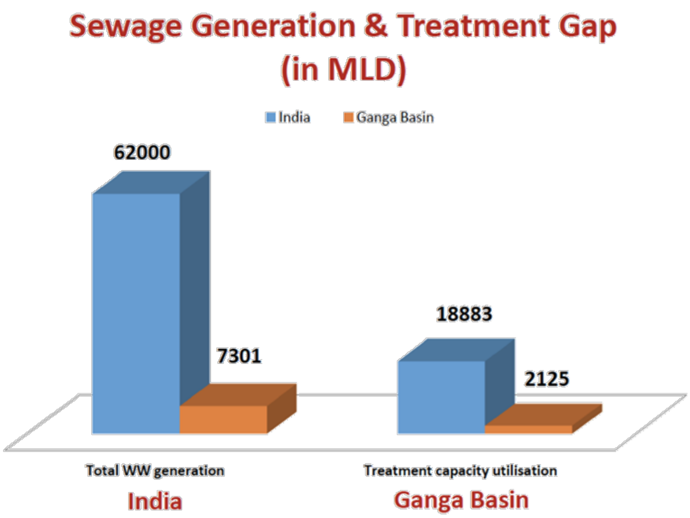


Figure 2 – Wastewater Generation and Installed Treatment Capacities in Ganga States

Source: Ministry of Environment, Forest and Climate Change, GoI, Loksabha unstarred question no. 2541, dated May, 2018.

It is estimated that 11 Ganga basin states generate 12050 MLD (Class I & II towns), whereas 5 Ganga Basin State along main river stem generate 7301 MLD wastewater (across 175 Class I & 102 Class II towns). On the contrary, only 2125 MLD treatment capacities are installed (3313 MLD including 1188 MLD under approval/construction). Considering the same, there is a shortfall of 8737 MLD treatment capacity across 11 Ganga Basin States and 3988 MLD in towns along the main river stem (*Source: CSE, February 2019*). This shows, high volumes of untreated wastewater entering Ganga River causing severe pollution.

Domestic wastewater contributes to 92% of pollution lead entering Ganga river, whereas rest is contributed by industries. However, in terms of organic pollution, domestic wastewater contributes 69%, whereas industries contribute 31%.



***Namami Gange – Centre's Flagship Program for Rejuvenation of Ganga River*[4]**

'Namami Gange' is a flagship program of Union Government initiated in 2014 with a budget outlay of INR 20,000 Crore to accomplish the twin objectives of effective abatement of pollution, conservation and rejuvenation of National River Ganga. The program's vision is to rejuvenate Ganga by restoring the wholesomeness of the river defined in terms of ensuring "Aviral Dhara" (continuous flow) and "Nirmal Dhara" (unpolluted flow), geologic and ecological integrity.

Nirmal Dhara is one of the 7 thrust areas under which actions for reducing pollution entering the river are targeted. Some of the actions are upgrading of existing Sewage Treatment Plants (STPs), creating additional treatment capacities and abatement of industrial pollution, which along with domestic wastewater are major contributors of pollution load.

As of May 2019, 298 projects worth INR 28,451.29 Crores have been sanctioned.

Table 2 – Sewage Infrastructure Projects - Status

S. No.	State	Status as on 31st May 2019				
		Projects	STP Capacity (MLD)	Completed	Work-in-progress	Tendering process
1	Uttarakhand	34	165.28	19	12	3
2	Uttar Pradesh	50	1622.16	13	20	18
3	Bihar	28	619.5	0	15	13
4	Jharkhand	2	15.5	0	2	0
5	West Bengal	22	864.67	3	7	12
6	Haryana	2	145	2	0	0
7	Delhi	11	1384.5	0	9	2
8	Himachal Pradesh	1	1.72	0	0	1
	Total	**150**	**4874.29**	**37**	**65**	**49**

Under this program, until May 2019, 483 MLD of treatment capacity has been created whereas 92 MLD created by rehabilitation of existing STPs. Sewer network of length 2576.28 km has been laid. Ongoing/planned actions include creating 3249 MLD of new treatment capacity along with 1022 MLD by rehabilitating existing STPs. Plan also includes laying of another 2394.73 km of sewer network.

Centralized Sanitation Systems – challenges

While the conventional sewerage may be a comprehensive system for sewage collection and transport, it also remains as a highly resource-intensive technology. Consequently, high capital cost and significant O&M cost of this system inhibits its widespread adoption in all sizes of urban areas. Conventional centralised sewerage systems require an elaborate infrastructure and large amounts of water to carry the wastes or excreta away. They are resource intensive - that is, they require energy, skilled labour, expensive infrastructure, operation and maintenance. Usually centralized systems are adopted when there are limited challenges in terms of cost, land resources and operative finances in place.

Adopting conventional centralised approach alone for managing wastewater in an urban setting might not eliminate completely the problem of untreated pollution loads entering the river. There is growing acceptance regarding decentralised wastewater management approaches, wherein the focus is on collecting and treating the waste at source or as near as possible to source of generation. This negates requirement of extensive conveyance infrastructure as required in sewerage system. The waste

[4] All information presented in this section is sourced from "Namami Gange Program – At a Glance", project brochure by NMCG, May 2019

streams (liquids and solids in wastewater) can be separately treated and also requires relatively simpler technologies for treatment. A city can have a combination of centralised, decentralised and on-site wastewater management system to meet the overall city sanitation.

Swachh Bharat Mission (SBM) has significantly contributed to reducing open defecation through provision of toilets with on-site containment for faecal matter. Ganga basin is fast becoming ODF and if faecal sludge is not managed properly then instead of reducing contamination, it will further add to Ganga's pollution (*CSE, 2019*).

2 Waste types and characteristics

2.1 Waste types

The urban water cycle is one of the key processes connecting human activity to natural systems. The health and well-being of both human population and environment is therefore dependent on the integration of urban water systems with the natural systems. The generation of liquid waste from human activities is unavoidable. However, not all humans produce the same amount of liquid waste. The type and amount of liquid waste generated in households are influenced by behavior, lifestyle and standard of living of the population as well as by the governing technical and judicial framework. (*Henze and Ledin, 2001*).

The different sanitation systems generate the following products:

Blackwater - is the mixture of urine, feces and flushing water along with anal cleansing water (if anal cleansing is practiced) or dry-cleaning material (e.g. toilet paper).

Greywater is used water generated through bathing, hand-washing, cooking or laundry. It is sometimes mixed or treated along with blackwater.

Urine is the liquid not mixed with any feces or water.

Brown water is blackwater without urine.

Domestic wastewater comprises all sources of liquid household waste: Blackwater and greywater. However, it does not include storm water.

Excreta is the mixture of urine and feces not mixed with any flushing water (although small amounts of anal cleansing water may be included).

Faecal Sludge is raw or partially digested in slurry or semisolid form, the collection, storage or treatment of combinations of excreta and black water, with or without grey water. It is the solid or settled contents of pit latrines and septic tanks. The physical, chemical and biological qualities of faecal sludge are influenced by the duration of storage, temperature, soil condition, and intrusion of groundwater or surface water in septic tanks or pits, performance of septic tanks, and tank emptying technology and pattern. *(Ministry of Housing and Urban Affairs, 2017)*

It is estimated that 1 truck of faecal sludge and septage carelessly dumped equals to 5,000 people defecating in open. 1 gram of feces may contain one hundred parasites eggs, one thousand protozoa, 10 lakh bacteria and 1 crore virus.

Septage is the liquid and solid material that is pumped from a septic tank, cesspool, or such on-site treatment facility after it has accumulated over a period of time. Septage is the combination of scum, sludge and liquid that accumulates in septic tanks.

The effluent from the septic tank can be collected in a network of drains and/or sewers and treated in a treatment plant designed appropriately. The accumulating sludge at the bottom of the septic tank however, has to be also removed and treated once it has reached the designed depth or at the end of the designed desludging frequency whichever occurs earlier. Such a removal is possible only by trucks. While sucking out the sludge, the liquid in the septic tank will also be sucked out. Such a mixture is referred to as septage. (National Policy on Faecal Sludge and Septage Management, 2017)

It is required to dispose septage safely otherwise it can impact on health. Due to wrong designs of the septic tanks and twin pits, waste water ends up mixing with ground water which can lead to water borne diseases and environmental issues.

Domestic wastewater comprises all sources of liquid household waste: Blackwater and greywater. However, it does not include stormwater.

Storm water in a community settlement is runoff from house roofs, paved areas and roads during rainfall events. It also includes water from the catchment of a stream or river upstream of a community settlement.

2.2 Parameters to characterise wastewater

Wastewater is mostly water by weight. Other materials make up only a small portion of wastewater but can be present in large enough quantities to endanger public health and the environment. Because practically anything that can be flushed down a toilet, drain, or sewer can be found in wastewater, even household sewage contains many potential pollutants.

The characteristics can be mainly divided into three categories; physical parameters, chemical parameters and biological parameters. In case of wastewater usually, measuring taste, odor etc. is not essential, but when it comes to water supply or primarily for drinking water color, odor, taste etc. are very important. And moreover, the solids present in water and wastewater are entirely different. In wastewater, mostly the solids are organic whereas in the raw water whatever is coming to the water treatment plant the solids may be mostly inorganically originating from clay silt and soil particles. And sometimes biological material also may be coming from plant fabrics and microorganisms.

2.2.1 Solids

Solids can be classified into various categories depending upon the size of the particles.

- TS- Total Solids
- TSS-Total Suspended Solids

If the particle size is very small if it is completely dissolved in the solution we can call it as dissolved solids. If the particle size is in between 0.01 micrometer to 1 micrometer, they are colloidal solids. These colloidal solids are very stable that means they will not be settling down in the liquid or water so they will always be in that Brownian motion, so it is very difficult to remove them especially from water and wastewater.

Suspended solids are those solids that do not pass through a 0.2-um filter. About 70% of those solids are organic, and 30% are inorganic. The inorganic fraction is mostly sand and grit that settles to form an inorganic sludge layer. Total suspended solids comprise both settleable solids and colloidal solids. Settleable solids will settle in an Imhoff cone within one hour, while colloidal solids (which are not dissolved) will not settle in this period. Suspended solids are easily removed by settling and/or filtration. However, if untreated wastewater with a high suspended solids content is discharged into the environment, turbidity and the organic content of the solids can deplete oxygen from the receiving water body and prevent light from penetrating.

2.2.2 Organic constituents

Organic materials are found everywhere in the environment. They are composed of the carbon-based chemicals that are the building blocks of most living things. Organic materials in wastewater originate from plants, animals, or synthetic organic compounds, and enter wastewater in human wastes, paper products, detergents, cosmetics, foods, and from agricultural, commercial, and industrial sources.

Organic compounds usually are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which means they can be consumed and broken down by organisms. Organic matter is determined by following characteristics;

- BOD - Biochemical oxygen demand
- COD - Chemical oxygen demand

Biodegradable organics are composed mainly of proteins, carbohydrates and fats. If discharged untreated into the environment, their biological stabilization can lead to the depletion of natural oxygen and development of septic conditions.

BOD test results can be used to assess the approximate quantity of oxygen required for biological stabilization of the organic matter present, which in turn, can be used to determine the size of wastewater treatment facilities, to measure the efficiency of some treatment processes and to evaluate compliance with wastewater discharge permits.

2.2.3 Nutrients

Wastewater often contains large amounts of the nutrients nitrogen and phosphorus in the form of nitrate and phosphate, which promote plant growth. Organisms only require small amounts of nutrients in biological treatment, so there is typically an excess available in treated wastewater.

In severe cases, excessive nutrients in receiving waters cause algae and other plants to grow fast depleting oxygen in the water. Deprived of oxygen, fish and other aquatic life die, emitting foul odours.

Nitrogen and phosphorus, also known as nutrients or bio stimulants, are essential for the growth of microorganisms, plants and animals. When discharged into the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life, which rob the water of dissolved oxygen. When discharged in excessive amounts on land, they can also lead to groundwater pollution.

2.2.4 Pathogens

Many disease-causing viruses, parasites, and bacteria also are present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals who are infected with or are carriers of a disease.

For example, greywater and blackwater from typical homes contain enough pathogens to pose a risk to public health. Other likely sources in communities include hospitals, schools, farms, and food processing plants

- TC (MPN) - Total coliforms, most probable number
- FC (MPN) - Fecal coliforms, most probable number

Pathogenic organisms present in wastewater can transmit communicable diseases. The presence of specific monitoring organisms is tested to gauge plant operation and the potential for reuse. Coliform bacteria include genera that originate in feces (e.g. Escherichia) as well as the genre not of faecal origin (e.g. Enterobacter, Klebsiella, Citrobacter). The assay is intended to be an indicator of faecal contamination; more specifically of E. coli which is an indicator microorganism for other pathogens that may be present in feces. Presence of faecal coliforms in water may not be directly harmful and does not necessarily indicate the presence of feces.

2.2.5 pH

The acidity or alkalinity of wastewater affects both treatment and the environment. Low pH indicates increasing acidity, while a high pH indicates increasing alkalinity (a pH of 7 is neutral). The pH of wastewater needs to remain between 6 and 9 to protect organisms. Acids and other substances that alter pH can inactivate treatment processes when they enter wastewater from industrial or commercial sources. Wastewater with an extreme concentration of hydrogen ions is difficult to treat biologically. If the concentration is not altered before discharge, the wastewater effluent may alter the concentration in natural waters, which could have negative effects on the ecosystem.

Alkalinity in wastewater results from the presence of calcium, magnesium, sodium, potassium, carbonates and bicarbonates, and ammonia hydroxides. Alkalinity in wastewater buffers (controls) changes in pH caused by the addition of acids. Wastewater usually is alkaline due to the presence of groundwater (which has high concentrations of naturally occurring minerals) and domestic chemicals. The alkalinity of wastewater is essential where chemical and biological treatment is practiced, in biological nutrient removal and where ammonia is removed by air stripping.

2.2.6 Electric conductivity

The measured EC value is used as a surrogate measure of total dissolved solids (TDS) concentration. The salinity (i.e. 'saltiness') of treated wastewater used for irrigation is also determined by measuring its electric conductivity.

2.2.7 Temperature

The wastewater temperature is commonly higher than that of local water supplies. Temperature affects chemical reactions, reaction rates, aquatic life, and the suitability for beneficial uses. Furthermore, oxygen is less soluble in warm than in cold water. The wastewater temperature is commonly higher than that of local water supplies. Temperature affects chemical reactions, reaction rates, aquatic life, and the suitability for beneficial uses. Furthermore, oxygen is less soluble in warm than in cold water.

2.3 Characteristics of domestic wastewater

2.3.1 Grey water

The composition of grey wastewater depends on sources and installations from where the water is drawn, e.g. kitchen, bathroom or laundry. The chemical compounds present originate from household chemicals, cooking, washing and the piping. In general greywater contains lower levels of organic matter and nutrients compared to conventional wastewater, since urine, feces and toilet paper are not included.

Water consumption in low-income areas with water scarcity and rudimentary forms of water supply can be as low as 20−30 litres per person and day. Greywater volumes are even lower in regions where rivers or lakes are used for personal hygiene and for washing clothes and kitchen utensils.

Households in affluent areas with piped water may, however, generate several hundred litres per day. In urban and peri-urban areas of low and middle-income countries, greywater is most often discharged untreated into stormwater drains or sewers – provided they exist –from where it flows typically into aquatic systems. This practice may lead to oxygen depletion, increased turbidity, eutrophication, as well as microbial and chemical contamination of aquatic systems.

2.3.2 Urine

The concentration of nutrients in the excreted urine depends on the nutrient and liquid intake, the level of personal activity and climatic conditions.

Urine, rich in nitrogen and phosphorus, can be used as fertilizer for most non-nitrogen-fixing crops after appropriate treatment to reduce potential microbial contamination.

Since spinach, cauliflower and maize are crops with a high nitrogen content, they respond well to nitrogen fertilization. The nutrients in urine are present in ionic form, and their plant availability and fertilizing effect compare well with those of chemical (ammonium and urea-based) fertilizers (Kirchmann and Petterson 1995, pp. 149−154; Johansson et al. 2001). Environmental transmission of urine-excreted pathogens is of minor concern in temperate climates. However, fecal cross-contamination may create a health risk. In tropical climates, fecal contamination of collected urine poses the primary health risk. Some (rare) urine- excreted pathogens should also be considered.

2.3.3 Feces

From a risk perspective, exposure to untreated feces is always considered unsafe because the high levels of pathogens whose prevalence is dependent on the given population. Enteric infections can be transmitted by pathogenic species of bacteria, viruses, parasitic protozoa, and helminths. (WHO 2006). Fecal compost can be applied as a complete phosphorus-potassium fertilizer or as a soil improver.

About 40−70% of the organic matter and slightly lower nitrogen content are lost through biological activity and volatilization. Most of the remaining nitrogen will become available to plants during degradation. The content of organic matter in feces also increases the water-holding and ion-buffering capacity of soils, an essential aspect to improving soil structure and stimulating microbial activity. (WHO 2006).

Table 3 – Characterisation of waste products

	Total	Grey water	Urine	Feces
Volume (L/cap.yr)	25,000-100,000	25,000-100,000	500	50
Nitrogen (kg/cap.yr)	2.0-4.0	5%	85%	10%
Phosphorus (kg/cap.yr)	0.3-0.8	10%	60%	30%
Potassium(kg/cap.yr)	1.4-2.0	34%	54%	12%
COD (kg/cap.yr)	30	41%	12%	47%
Faecal coliform (per 100 mL)	-	10^4-10^6	0	10^7-10^9

Source: SANDEC, 2004

3 Sanitation systems and technologies

3.1 What is a Sanitation System

A Sanitation System is a context-specific series of technologies and services for the management of these wastes (or resources), i.e. for their collection, containment, transport, transformation, utilization or disposal. A sanitation system is comprised of Products (wastes) which travel through Functional Groups which contain Technologies which can be selected according to the context. By selecting a Technology for each Product from each applicable Functional Group, one can design a logical Sanitation System. A sanitation system also includes the management, operation and maintenance (O&M) required to ensure that the system functions safely and sustainably.

Table 4 – Classification of Sanitation Systems

Waterborne or Wet – Requires water for its functioning	Non-Waterborne or dry – No need water for its functioning
• Full flush or cistern flush (water comes from the cistern) • Pour flush (use of bucket to throw water for flushing purpose) • Low flush toilet (flushing mechanism release small quantity of water) • Aqua privy	• Urine diverting dry toilet (UDDT) • Dry toilet (sit or squat pan) • VIP toilet • Vault toilet

Sanitation systems can be mainly classified as waterless and water-based systems. Classification is usually defined by user interface and collection technology. Waterless systems are single pits, Waterless Alternating Double Pits and waterless urine diversion systems whereas, the water-based systems are Pour Flush with Urine Diversion, Decentralized Blackwater Treatment, (Semi-) Centralized Blackwater Treatment, Sewerage with (Semi-) Centralized Treatment.

3.2 What are the Functional Groups of a sanitation system?

A sanitation system should consider all the products generated and all the Functional Groups these products are subjected to before being suitably disposed of. Domestic products mainly run through five different Functional Groups, which form together a system. A functional group is a grouping of technologies that have similar functions. There are five different functional groups from which technologies can be chosen to build a system. However, it is worth noting that depending on the system, not every Functional Group is required.

The five functional groups that forms a sanitation system are mentioned below:

- User Interface
- Containment and Storage/Treatment
- Conveyance
- Treatment
- Use and/or Disposal

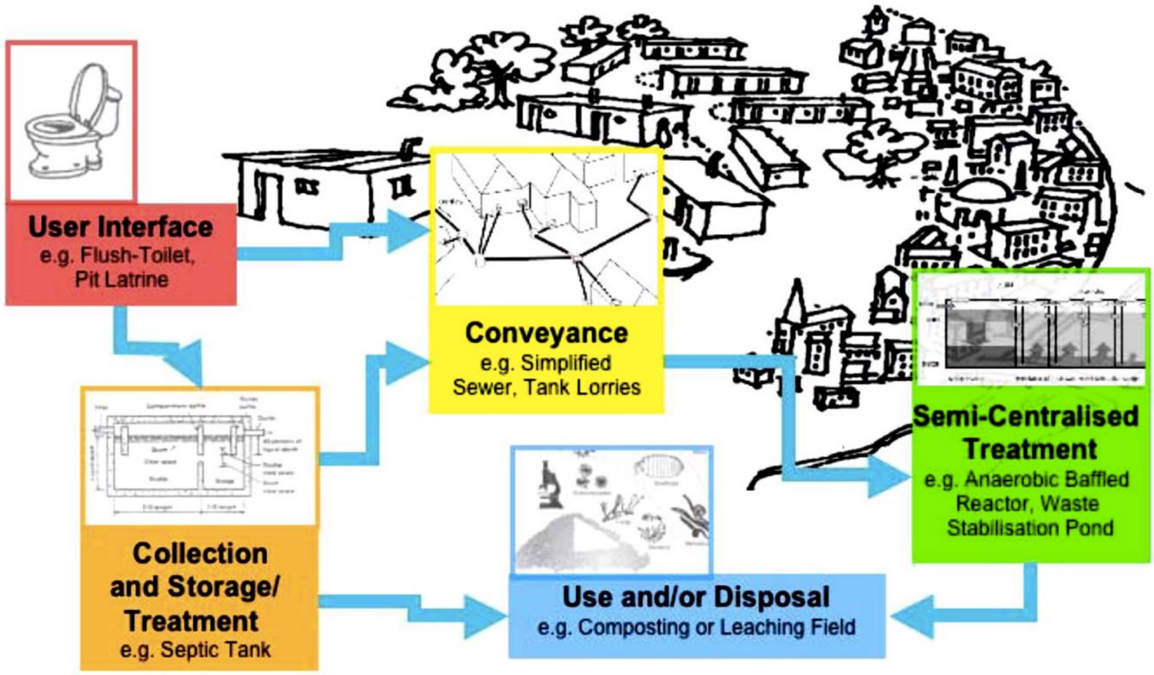


Figure 3 – Functional groups of sanitation

Source: SANDEC (2008)

<u>*Selection of appropriate sanitation systems*</u>

A system is a set of technologies, each processing the products until they are ultimately disposed of. In other words, processing all the waste products "from the cradle to the grave" should be considered. Though the system templates (i.e. groups of processes and products) are predefined, the exact system and favoured technologies still have to be selected from among the options provided. The choice is context-specific and should be made by the local environment, culture and resources. Despite the different technology options available, a comprehensive study of the specific situation is necessary before making the final decision (*Tilley 2008*).

The steps required when selecting a site-specific system:

- Identify the types of products generated or those the stakeholders would be willing to produce (e.g. separated urine).
- Select the most feasible systems, i.e. the systems that include the appropriate products and number of process steps the stakeholders would be willing to operate and maintain.
- Select the specific technologies for each product for each process in each of the systems identified.
- Select one of the systems based on the social, economic and resource aspects of the associated technologies

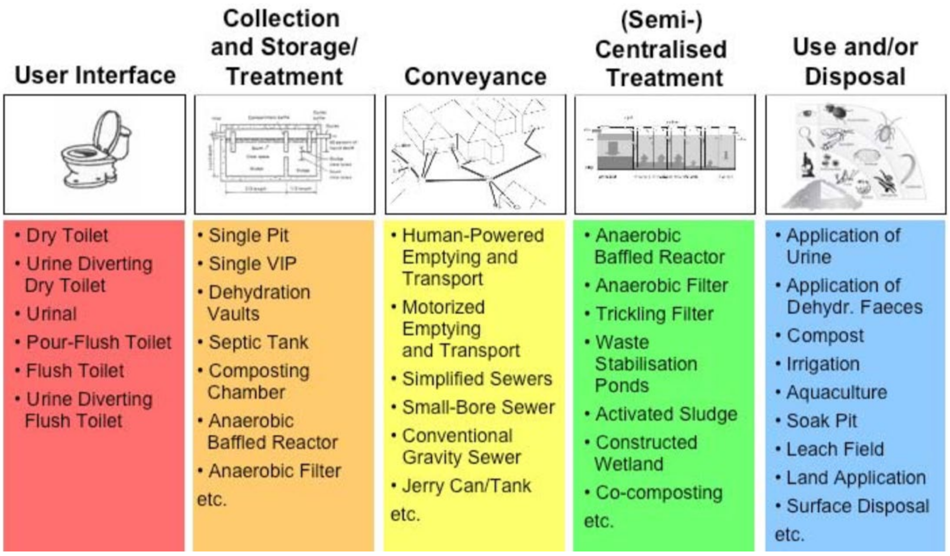


Figure 4 – Main Processing Systems of Sanitation

3.2.1 Functional group – User Interface

The user interface must guarantee that human excreta is hygienically separated from human contact to prevent exposure to fecal contamination. The user interface is the way in which the sanitation system is accessed. Choice of the user interface has a significant impact on the entire system design, as it defines the products or product mixtures fed into the system. Therefore, the user interface strongly influences the technological choices of subsequent processes. Selection of user interface depends on the following six technical and physical criteria.

- Availability of space
- Ground condition
- Groundwater level and contamination
- Water availability
- Climate

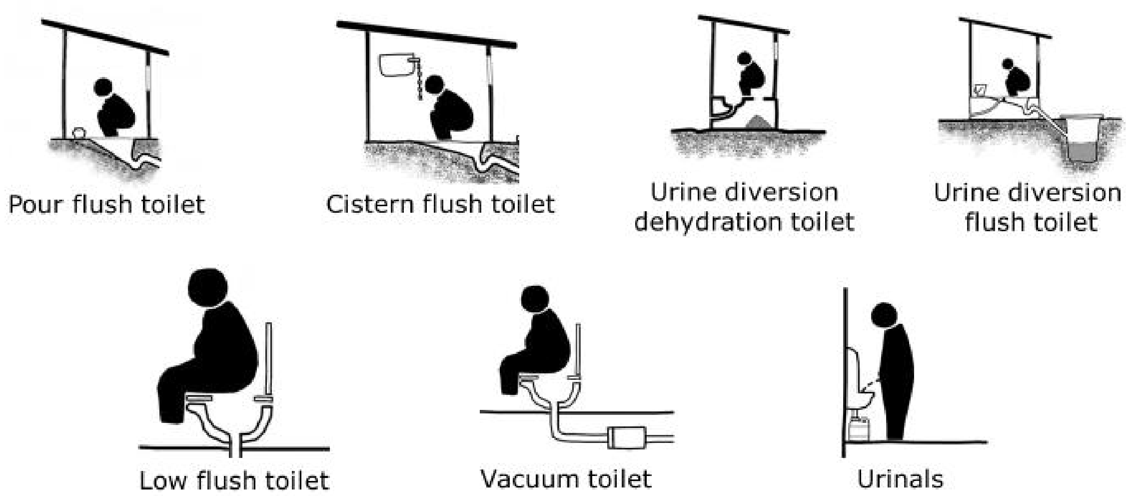


Figure 5 – User Interface Options

3.2.2 Functional group - Containment and storage treatment

This section explains how the output products of a user interface can be collected, stored, and treated on-site. The functional group on-site containment system describes the ways of receiving, storing, and sometimes treating the products generated at the user interface. The treatment provided by these technologies is often the function of storage, and is usually passive, without requiring energy input. Products that emanate from these technologies often require subsequent treatment before use or disposal. There's quite a wide range of technologies which belong to this functional group. The technical and physical criteria for choosing appropriate collection, storage and treatment technology are as follows;

- Ground condition (Soil and strata (percolation and cost of construction)
- Groundwater level and contamination (Cross contamination (pathogens))
- Climate-Temperature (degree of treatment) and rainfall (percolation rate)

Containment systems for excreta management can be broadly categorized into two, offsite sanitation systems and On-site sanitation systems (OSS). Offsite sanitation systems carry the wastewater collected from the toilet to a single point of collection and treatment or outlet to water bodies. In OSS systems, faecal waste is collected in a containment system and may or may not be treated.[5] OSS systems range from a basic sanitary facility, such as single pit and twin-pit latrines, to a treatment system that connects a septic tank with a soak pit or a bio-digester toilet (aerobic and anaerobic).

[***Off-site sanitation systems have been further elaborated under section Decentralised Wastewater Management, whereas OSS systems have been elaborated under Faecal Sludge and Septage Management***]

3.2.3 Functional group - Conveyance

If waste products cannot be safely disposed of or even suitably reused on site, they have to be transported elsewhere. Conveyance describes the way in which products are moved from one process to another. Although products may need to be moved in various ways to reach the required process, the longest and most important gap lie between on-site storage and (semi-) centralised treatment.

The technical and physical criteria for choosing appropriate conveyance technology/system are as follows;

- Water availability,
- Ground condition,
- Ground water level and contamination

[5] Retrieved from *Septage Management: A Practitioner's Guide*, Centre for Science and Environment, New Delhi

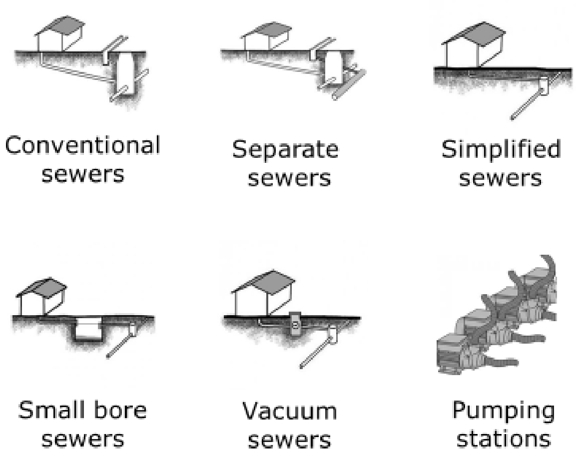


Figure 7 – Sewered Conveyance Options

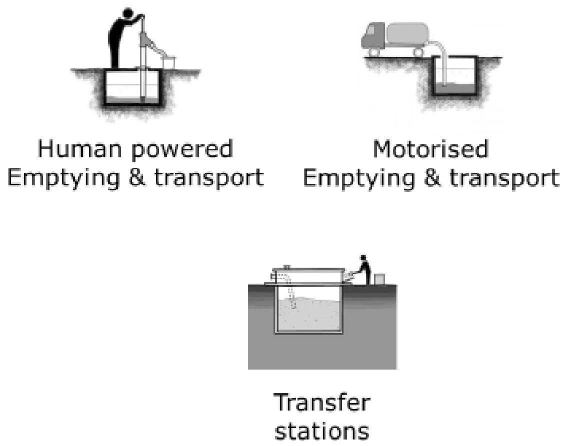


Figure 6 – Non-sewered conveyance options

The wastewater from households (blackwater and greywater) can be conveyed through various types of networked system (sewers) for off-site treatment whereas faecal sludge/septage from OSS needs to be emptied and transported to off-site treatment facility through motorized or manual emptying/transport options.

[Sewered conveyance options have been discussed under section decentralised wastewater management systems, whereas non-sewered conveyance options are discussed under section Faecal Sludge and Septage Management]

3.2.4 Functional Group – Treatment

To design an appropriate treatment system, it is important to combine the technologies in order to achieve the desired overall treatment objectives (e.g. multiple stage configuration for pre-treatment, primary treatment and secondary treatment). It is important to consider the following factors as,

- Type and quantity of products to be treated (including future developments)
- Desired output product (end-use and/or legal quality requirements)
- Financial resources
- Local availability of materials
- Availability of space
- Soil and groundwater characteristics
- Availability of a constant source of electricity
- Skills and capacity (for design and operation)
- Management considerations

[The basics of wastewater treatment and related treatment technologies have been elaborated under section Decentralised Wastewater Management, whereas basics of faecal sludge/septage from on-site sanitation systems have been elaborated under section Faecal Sludge and Septage Management]

4 Decentralised Wastewater Treatment (DWWT) Systems[6]

4.1 Introduction

Decentralized wastewater treatment (DWWT) systems treat wastewater of individual houses, apartment blocks or small communities close to their origin. Typically, the decentralized system is a combination of many technologies within a given geographical boundary, namely, onsite systems, low cost collection systems and dispersed siting of treatment facilities. Wastewater treatment systems such as pit latrines, septic tanks, DEWATS etc., which are used for partially treating wastewater in individual residences or a small cluster of houses, are termed as "On Site Wastewater Treatment (OSWT)" systems. OSWT need not have any wastewater collection system, while a DWWT may have a small sewerage system (*IIT Madras, Chennai, 2012*).

In decentralized approach, more than one, small capacity of treatment plant can be set up across the city. It could be in the cluster of residential areas, in commercial areas, at the individual scale or in the industrial areas. Decentralised wastewater treatment solutions include both smaller community scale or individual wastewater treatment module and the management (collection, transport, treatment and disposal) of the contents of non-sewered on-site sanitation systems like single pit latrines, twin pit latrines, septic tanks, holding tanks, aqua privies etc.

Decentralised systems are suitable in situations where community / institutional facility is far away from the existing centralized system, implementing system is unaffordable, topographical constraints in connecting all parts of the towns (specially low lying areas), localities where there is scarcity of freshwater, where there is possibility for localised reuse of treated wastewater and newly developing residential, commercial and institutional areas.

A city or town can have a combination of centralized, decentralized and on-site wastewater management systems, to meet the overall city sanitation

Since decentralised systems aim at providing incremental scaling of infrastructure to optimise investments, these systems are typically designed for 15 years unlike centralised sewage treatment systems that are designed for 30 years.

4.1.1 Advantages of Decentralised Wastewater Treatment Systems

a) Cost efficient
- The requirement for the underground sewer system is completely eliminated or partially required (within the settlement area from the household to the decentralised treatment system).
- Lower capital cost and O&M costs, due to absence of complex mechanical as well as electrical systems associated.

b) Environment Friendly
- Complete absence or lower electric consumption and hence power saving.
- Due or absence of underground sewer system, negligible possibility of ground water contamination.
- Odorless, hence can be built within a living habitat also.

[6] Source: Guidelines for Decentralised Wastewater Management, prepared by MoUD Centre of Excellence in DWWM Department of Civil Engineering, Indian Institute of Technology Madras, 2012

c) High user acceptance
  - Minimal O&M needs and costs as lower human resources capacity levels needed.
  - Easy and efficient user involvement and participation (e.g. in decision making and O&M).

d) Flexibility in scale
  - Can be built easily at remotest places, even by regularly skilled labour.
  - Can be built for a scale fit for a household, cluster as well as community level or a town level.

4.1.2 Disadvantages of Decentralised Wastewater Treatment Systems

Even where policy-makers accept the decentralized approach, they may lack the capacity to plan, design, implement, and operate decentralized systems, thus leading to severe constrains in ensuring its widespread implementation.

Most developing countries have no suitable institutional arrangements for managing decentralized systems and lack an appropriate policy framework to promote a decentralized approach. There is a risk that decentralisation will lead to fragmentation and failure to address overall problems adequately. Without technical assistance and other capacity building measures, problems of institutional capacity existing under a centralised operation are simply passed on to the new structures.

Without a formal institutional framework within which decentralized systems can be located, efforts to introduce decentralized management are likely to remain fragmented and unreliable. Decentralisation therefore requires greater coordination between the government, private sector and civil society. Decentralized systems must be compatible with the knowledge and skills available at local level, as even the simplest technologies often fail in practice for lack of attention to operational and maintenance requirements.

As in the case of centralised wastewater management, decentralised wastewater treatment systems have the following components

- Wastewater collection system
- Wastewater treatment system
- Reuse/disposal system

4.2 Decentralised Wastewater Collection System[7]

Simplified sewer systems are cost-effective alternative approaches to overcome the challenges of implementing conventional systems mainly pertaining to costs in laying sewer lines, installation challenges and thereafter maintenance issues. Conventional systems and simplified sewer systems are conceptually the same, with later one focussing on eliminating unnecessary conservative design features and matching design standards to local situation. The whole idea is to simplify the design and reduce the costs for laying the sewer system. Two approaches mentioned below fall under the ambit of simplified sewer systems.

- Shallow Sewer System
- Small Bore Sewer System

[7] In this section, conveyance options for transporting wastewater to an off-site for treatment have been discussed. Non-sewered options for on-site sanitation have been discussed under Faecal Sludge and Septage Management

4.2.1 Shallow Sewer System

Also referred to as condominial sewerage, is used to convey both blackwater and greywater from a household to an offsite location through sewer lines laid at shall depth for treatment and safe disposal. The design and implementation of this system mainly involves applying design principles of simplified sewers coupled with consultations with users and planning and implementation agencies. The successful implementation of these system is largely dependent on participation of local community, since sewer lines need to cross private property boundaries.

The main feature of this system is that sewers are routed through private land (either in back or front yards of the property). Shallow sewers are usually laid in the front or back yards of the house plots (suited for neighbourhoods with challenging topography or urbanization patterns) or under the pavement (sidewalk).

The system is suitable for (a) high density and squatter settlements (b) newly planned settlements where currently there is no option to dispose household wastewater through conventional sewer system (c) adverse ground conditions and where on-site disposal is not possible and (d) for sullage disposal and where minimum rate of water consumption is 25 lpcd.

A shallow sewer system follows the hydraulic theory of conventional sewerage, however its design assumptions are less conservative. Smaller diameter pipes are used and minimum earth cover could be as low as 0.2 m if less traffic volume expected. Such systems are designed with a planning horizon of 30 years.

The maintenance requirements for the system mainly includes individual households maintaining their interceptor tanks and grease traps, periodical cleaning of inspection chambers and avoiding grit and storm water entering in the collection system.

Pros	**Cons**
• smaller diameter pipes and shallow inspection chambers resulting in lower CAPEX and OPEX compared to conventional system • system can be built with locally available materials and repaired locally • can be incrementally expanded as per need • cost of construction could be 30 to 50% lower than conventional sewerage depending on local conditions	• requires expert design and construction supervision • suitable only where adequate ground slope available • frequent clogging of sewers, requires frequent cleaning as solids likely to get deposited because of flat • reluctance by households to allow laying of sewers through their properties

4.2.2 Small Bore Sewer System (Also referred to as Settled Sewer System)

The system is designed to collect only the liquid portion of the domestic wastewater (blackwater & greywater) and transport to on-site or off-site location for treatment and safe disposal. The solids are retained in septic tanks or interceptor tanks at household level before it enters the sewer system. Since the system collects only settled wastewater, the water requirements for transporting the solids and self-cleansing velocities are less. The system is suitable for following conditions:

- where there is no possibility of on-site/off-site effluent disposal from toilets and bathrooms/kitchens
- area where interventions for improvements are incrementally planned by provision of small-bore sewer system first followed by gradual upgradation to full scale conventional system

- where ground and soil conditions do not allow for effluent from on-site systems to be discharged locally

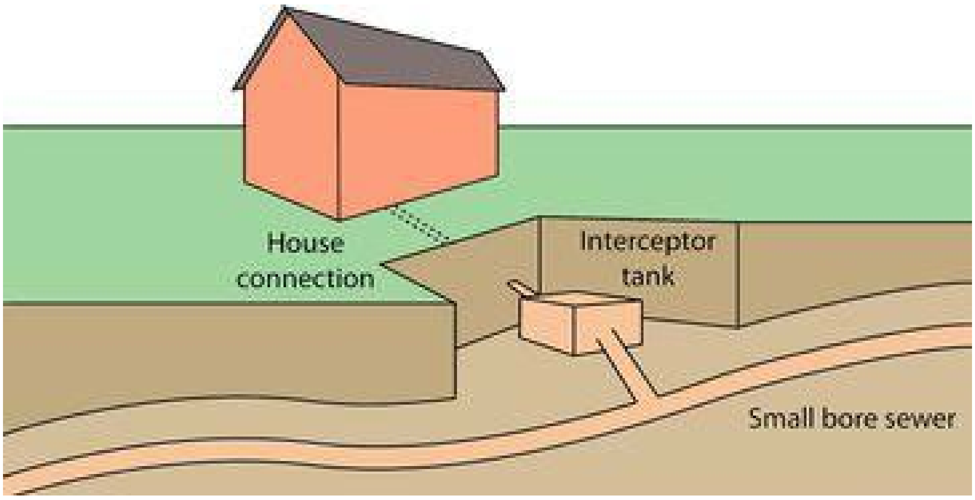


Figure 8 – Schematic diagram of small bore sewer system

The minimum diameter of sewer pipe is 100 mm. The system does not require to maintain strict gradients for self-cleansing velocities. The sewer may be constructed with any profile provided the hydraulic gradient is maintained below the levels of interceptor tanks.

The optimal functioning of this system to a large extent depends on households getting their septic tanks and interceptor tanks cleaned on regular basis. Flushing of sewers is recommended once a year as part of the regular maintenance regardless of their performance.

Pros	Cons
• reduced water requirements for transportation of solids • lesser excavation and construction material cost as compared to conventional system • treatment requirements are less since solids are already retained on-site • reduced maintenance requirements	• regular cleaning of septic/interceptor tanks • requires well-planned maintenance system • mixed experience with the system (limited experience) • possibility of solids entering sewer system due to illegal connection

4.2.3 Twin Drains

The twin drain system comprises of a integral twin drain on both sides of the road, the drain nearer to the property carrying the septic tank effluent & the grey water and the drain on the road side for storm water and the sewer drains are interconnected to flow out to treatment. This system is in use in coastal areas of Tamil Nadu particularly in Tsunami affected habitations.

4.3 Decentralised Wastewater Treatment Systems

Decentralised wastewater treatment is a system where the treatment of wastewater (sewage) takes place at the same location where it is generated (on-site) or is transported through a simplified conveyance system and is treated within a short distance of its generation.

Decentralised wastewater treatment system can be designed using specific treatment modules that can be used in various combinations depending on various factors like wastewater strength and volume, space availability, intended re-use of treated by-products, required investment etc. The applications are designed and dimensioned in such a way that treated effluent or wastewater meets requirements stipulated in environmental laws and regulations.

Compared to household-centered storage technologies (*refer section on Faecal sludge and septage management*), these treatment technologies are designed to accommodate increased volumes of flow and provide, in most cases, improved removal of nutrients, organics and pathogens. The technical and physical criteria for choosing appropriate technology for treatment are as follows;

- Availability of space and other resources (Choice of technology)
- Climate (Temperature affects rate of reactions)
- Ground condition (Flood-prone area)
- Groundwater level and contamination (Cross contamination from tanks underground)

4.3.1 Basics of Wastewater Treatment

4.3.1.1 Quantification of Sewage

Quantification of sewage is an important aspect in designing of wastewater treatment system. It is considered that the net quantity of sewage involves accounted quantity of water supplied for the daily use from the water supply department and unaccounted private water supplies (e.g. wells, borewells etc). It also involves the infiltration during wet season and water losses from the sewers. It is considered that around 75 - 80% of sewage generated from the total accounted water supply.

4.3.1.2 Characterisation of Sewage

It is important to consider the concentration of various parameters while designing the sewage treatment plant.

Item	Per capita contribution (g / c /d)	water supply (L / c / d)	Sewage Generation 80 % of (3)	Concen-tration (mg/L)
(1)	(2)	(3)	(4)	(5)
BOD	27.0	135	108	250.0
COD	45.9	135	108	425.0
TSS	40.5	135	108	375.0
VSS	28.4	135	108	262.5
Total Nitrogen	5.4	135	108	50.0
Organic Nitrogen	1.4	135	108	12.5
Ammonia Nitrogen	3.5	135	108	32.5
Nitrate Nitrogen	0.5	135	108	5.0
Total Phosphorus	0.8	135	108	7.1
Ortho Phosphorous	0.5	135	108	5.0

Illustration BOD = 27 *1000 (mg) / 135 X 0.8 (litres) = 250 mg/L

Figure 9: Concentration of various parameters in the absence of drain or outfall

The raw sewage characteristics are a function of level of water supply and per capita pollution load. Thus, the level of water supply plays a major role in deciding the concentration of pollutants. Other significant factors are settlement and decomposition in sewers under warm weather conditions, partially decomposed sewage from septic tanks, lifestyle of the population, etc. The best way to ascertain the sewage characteristics is to conduct the composite sampling once a week for diurnal variation on hourly basis from the nearby existing sewage outfall or drain. Based on the raw sewage quality monitoring experiences, the following typical concentrations can be taken for design purpose for 135 Litres/Capita/day water supply.

4.3.1.3 Wastewater Treatment Processes

The wastewater treatment processes are usually classified as,

- Physical unit operations
- Biological unit processes
- Chemical unit processes
- Photolytic unit processes

Physical Unit Operations: Treatment methods in which the application of physical forces predominates are known as physical unit operations. Most of these methods are based on physical forces, e.g. screening, mixing, flocculation, sedimentation, flotation, and filtration.

Chemical Unit Processes: Treatment methods in which removal or conversion of contaminant is brought by addition of chemicals or by other chemical reaction are known as chemical unit processes, for example, precipitation, gas transfer, adsorption, and disinfection.

Biological Unit Processes: Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes.

- This is primarily used to remove biodegradable organic substances from the wastewater, either in colloidal or dissolved form.
- In the biological unit process, organic matter is converted into gases that can escape to the atmosphere and into bacterial cells, which can be removed by settling.
- Biological treatment is also used for nitrogen removal and for phosphorous and sulphate removal from the wastewater.

4.3.2 Wastewater Treatment Chain

Typical wastewater treatment chain involves the following stages,

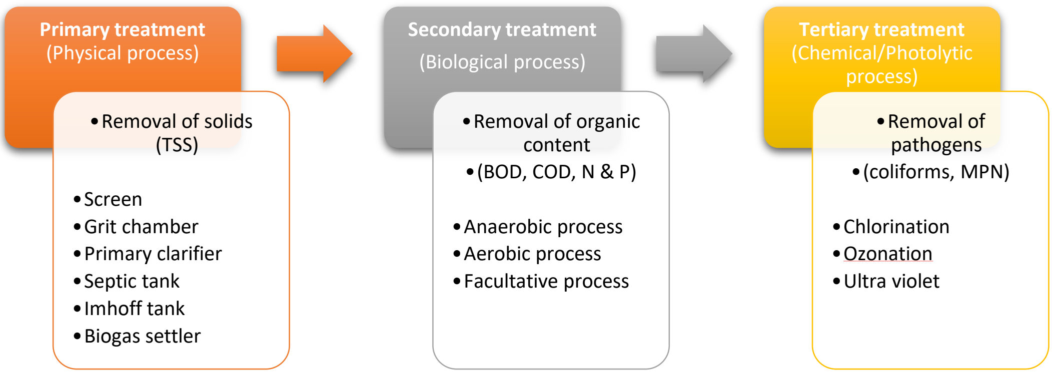


Figure 10 – Wastewater Treatment Chain

4.3.3 Primary Treatment

4.3.3.1 Screens

Screening aims to prevent coarse solids, such as plastics, rags and other trash, from entering a sewerage system or treatment plant. Solids get trapped by inclined screens or bar racks. The spacing between the bars usually is 15 to 40 mm, depending on cleaning patterns. Screens can be cleaned by hand or mechanically raked. The latter allows for a more frequent solids removal and, correspondingly, a smaller design. The screening may consist of parallel bars, rods, gratings or wire mesh or perforated plates and the openings may be of any shape, although generally they are contrived from circular or rectangular bars. It is recommended that three sequential stages of screens shall be provided being coarse, followed by medium and followed by fine screens

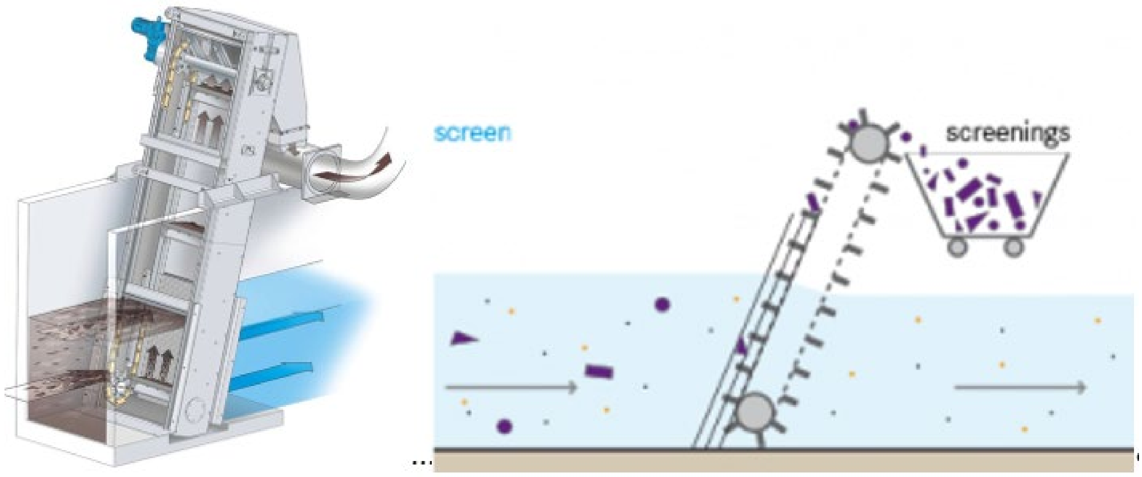


Figure 11 - Schematic diagram of screens

4.3.3.2 Grit Chamber

Where subsequent treatment technologies could be hindered or damaged by the presence of sand, grit chambers (or sand traps) allow for the removal of heavy inorganic fractions by settling. There are three general types of grit chambers: horizontal-flow, aerated, or vortex chambers. All of these designs allow heavy grit particles to settle out, while lighter, principally organic particles remain in suspension.

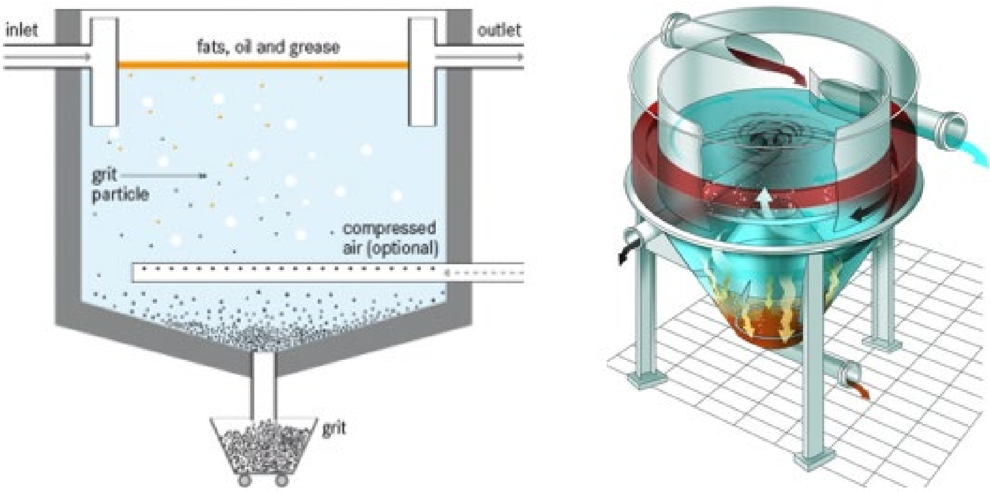


Figure 12 – Schematic diagram of grit chamber

4.3.3.3 Primary Clarifier

The primary clarifier generally removes 30 to 40% of the total BOD and 50 to 70% of suspended solids from the raw sewage. The flow through velocity of 1 cm/sec at average flow is used for design with detention period in the range of 90 to 150 minutes. This horizontal velocity will be generally effective for removal of organic suspended solids of size above 0.1 mm. Primary sedimentation tanks can be circular or rectangular tanks designed using average dry weather flow and checked for peak flow condition. The numbers of tanks are determined by limitation of tank size. The diameter of circular tank may range from 3 to 60 m (up to 45 m typical) and it is governed by structural requirements of the trusses which supports scrapper in case of mechanically cleaned tank. Rectangular tank with length 90m are in use, but usually length more than 40 m are not preferred.

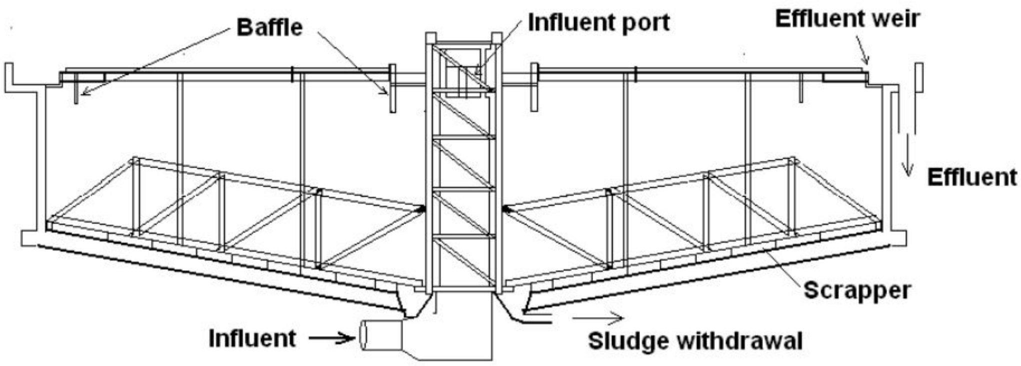


Figure 13 - Schematic diagram of primary clarifier

The depth of mechanically cleaned tank should be as shallow as possible, with minimum 2.15 m. The average depth of the tank used in practice is about 3.5 m. The floor of the tank is provided with slope 6 to 16 % (8 to 12 % typical) for circular tank and 2 to 8% for rectangular tanks.

4.3.3.4 Septic Tank

A septic tank is a watertight chamber made of concrete, fibreglass, PVC or plastic, through which blackwater and greywater flows for primary treatment. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate.

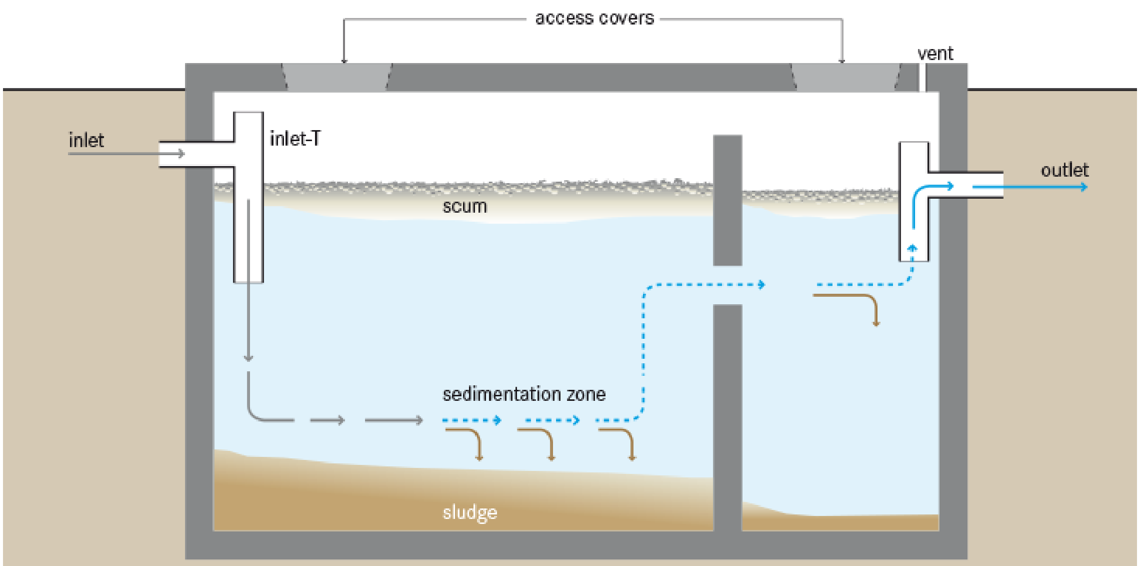


Figure 14 - Schematic diagram of septic tank

4.3.3.5 Imhoff Tank

The Imhoff tank (also known as Emscherbrunnen or Emscher Tank), which works similar to a communal septic tank, is a robust and effective settler that causes a suspended solids reduction of 50 to 70%, COD reduction of 25 to 50%, and leads to potentially good sludge stabilisation – depending on the design and conditions. It is a compact and efficient system for pre-treatment of municipal wastewater. The settling compartment has a circular or rectangular shape with V-shaped walls and a slot at the bottom, allowing solids to settle into the digestion compartment, while preventing foul gas from rising up and disturbing the settling process.

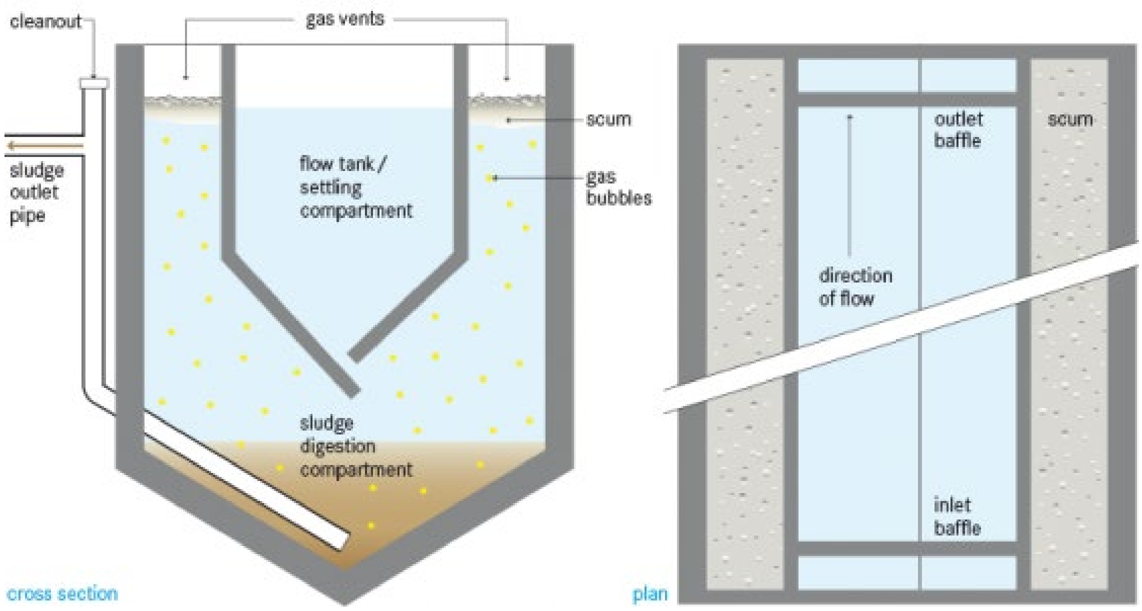


Figure 15 - Schematic diagram of Imhoff tank

4.3.3.6 Biogas Settler

A settler is a primary treatment technology for wastewater; it is designed to remove suspended solids by sedimentation. The main purpose of a settler is to facilitate sedimentation by reducing the velocity and turbulence of the wastewater stream.

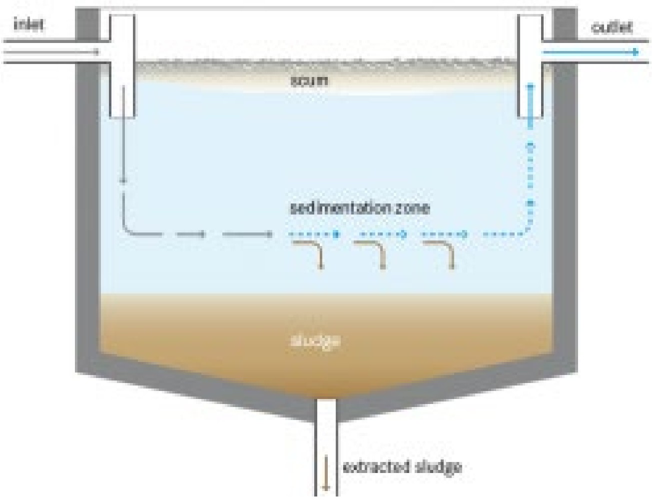


Figure 16 – Schematic diagram of Anaerobic/biogas Settler

Settlers are circular or rectangular tanks that are typically designed for a hydraulic retention time of 1.5-2.5 h. Less time is needed if the BOD level should not be too low for the following biological step.

4.3.4 Secondary Treatment

4.3.4.1 Waste Stabilisation Ponds

Waste Stabilization Ponds (WSPs) are large, man-made water bodies. The ponds can be used individually or linked in a series of improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. For the most effective treatment, WSPs should be linked in a series of three or more with the effluent being transferred from the anaerobic pond to the facultative pond and, finally, to the aerobic pond. Anaerobic and facultative ponds are designed for BOD removal, while aerobic ponds are designed for pathogen removal (see also pathogens and contaminants).

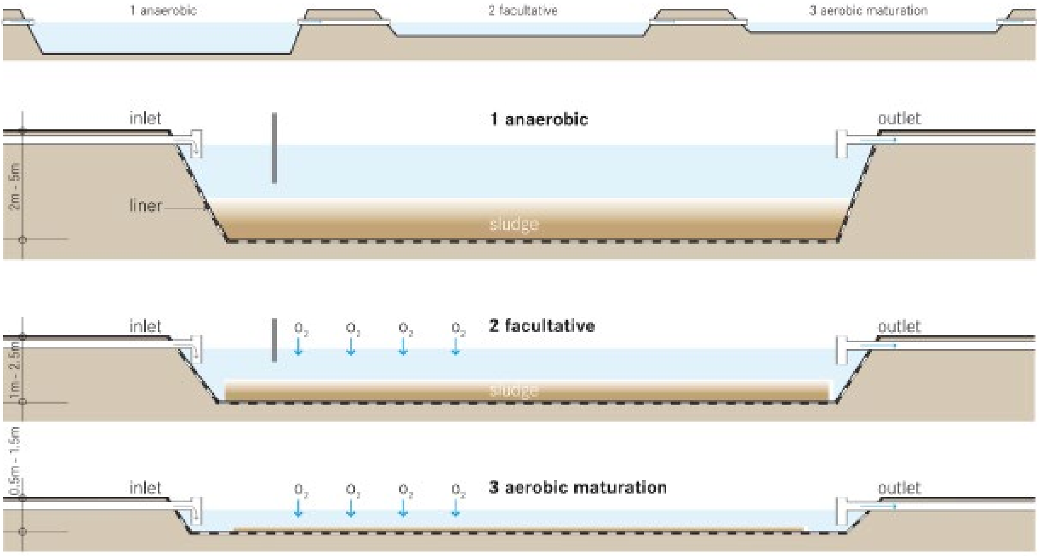


Figure 17 – Schematic diagram of WSP

WSPs are among the most common and efficient methods of wastewater treatment around the world. They are especially appropriate for rural communities that have large, open and unused lands, away from homes and public spaces and where it is feasible to develop a local collection system. They are not appropriate for very dense or urban areas.

Pros	Cons
• Resistant to organic and hydraulic shock loads • High reduction of solids, BOD and pathogens • High nutrient removal if combined with aquaculture • Low operating cost • No electrical energy required • No real problems with flies or odours if designed and maintained correctly	• Requires large land area • High capital cost depending on the price of land • Requires expert design and construction • Sludge requires proper removal and treatmentEffluent and sludge require further treatment and/or appropriate discharge

4.3.4.2 Up-flow Anaerobic Sludge Blanket Reactor (UASB)

The up-flow anaerobic sludge blanket reactor (UASB) is a single tank process. Wastewater enters the reactor from the bottom and flows upward. A suspended sludge blanket filters and treats the wastewater as the wastewater flows through it. The sludge blanket is comprised of microbial granules (1 to 3 mm in diameter), i.e., small agglomerations of microorganisms that degrade organic compounds. As a result, gases (methane and carbon dioxide) are released. The rising bubbles mix the sludge without the assistance of any mechanical parts. Sloped walls deflect material that reaches the top of the tank downwards. The clarified effluent is extracted from the top of the tank in an area above the sloped walls.

UASB is not appropriate for small or rural communities without constant water supply or electricity. The technology is relatively simple to design and build, but developing the granulated sludge may take several months. The UASB reactor has the potential to produce higher quality effluent than Septic Tanks and can do so in a smaller reactor volume. Although it is a well-established process for largescale industrial wastewater treatment and high organic loading rates up to 10 kg BOD/m3/d, its application to domestic sewage is still relatively new.

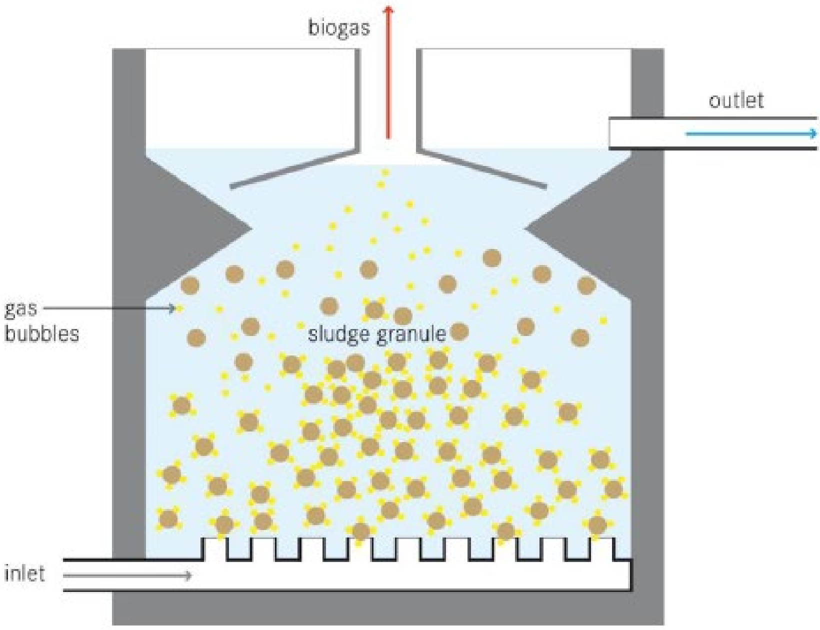


Figure 18 – Schematic diagram of UASB

Pros	Cons
• High reduction of BOD • Can withstand high organic and hydraulic loading rates • Low sludge production (and, thus, infrequent desludging required) • • Biogas can be used for energy (but usually first requires scrubbing)	• Treatment may be unstable with variable hydraulic and organic loads • Requires operation and maintenance by skilled personnel; difficult to maintain proper hydraulic conditions (Up-flow, and settling rates must be balanced) • Long start-up time to work at full capacity • A constant source of electricity is required • Not all parts and materials may be locally available • Requires expert design and construction

Pros	Cons
	• Effluent and sludge require further treatment and/or appropriate discharge

4.3.4.3 Activated Sludge Treatment

An activated sludge process refers to a multi-chamber reactor unit that makes use of highly concentrated microorganisms to degrade organics and remove nutrients from wastewater to produce high-quality effluent. To maintain aerobic conditions and to keep the activated sludge suspended, a continuous and well-timed supply of oxygen is required. Different configurations of the activated sludge process can be employed to ensure that the wastewater is mixed and aerated in an aeration tank. Aeration and mixing can be provided by pumping air or oxygen into the tank or by using surface aerators.

An activated sludge process is only appropriate for a Centralized Treatment facility with a well-trained staff, constant electricity and a highly developed management system that ensures that the facility is correctly operated and maintained. Because of economies of scale and less fluctuating influent characteristics, this technology is more effective for the treatment of large volumes of flows. An activated sludge process is appropriate in almost every climate. However, treatment capacity is reduced in colder environments.

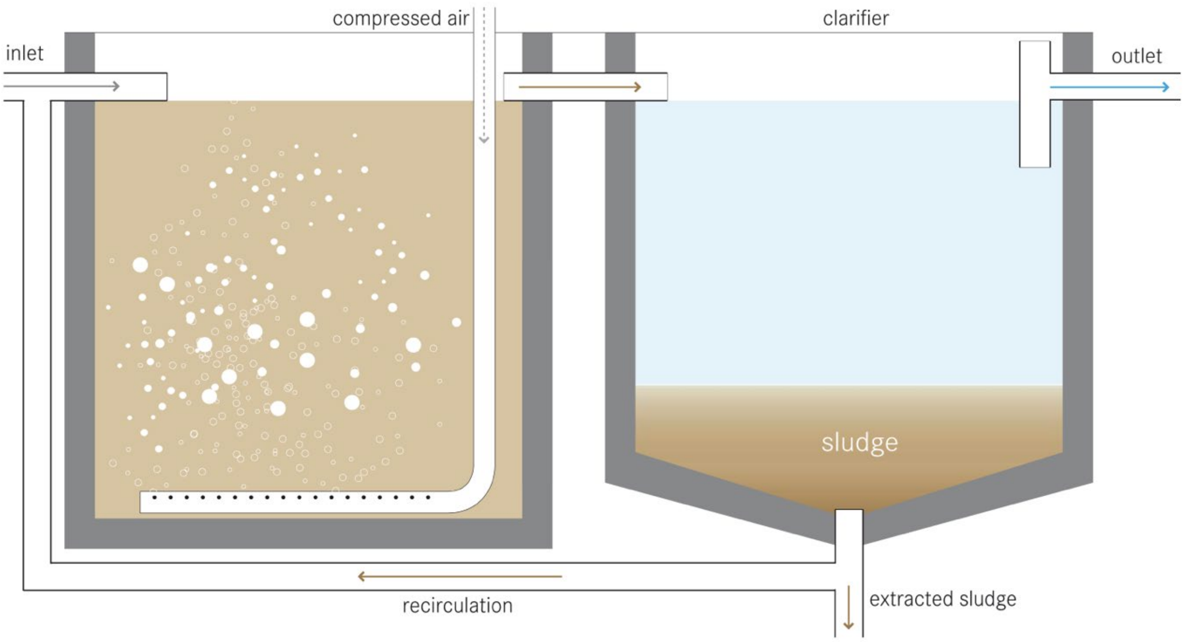


Figure 19 – Schematic diagram of ASP

Pros	Cons
• Resistant to organic and hydraulic shock loads • Can be operated at a range of organic and hydraulic loading rates • High reduction of BOD and pathogens (up to 99%) at after secondary treatment • High nutrient removal possible	• High energy consumption, a constant source of electricity is required • High capital and operating costs • Requires operation and maintenance by skilled personnel

Pros	Cons
• Can be modified to meet specific discharge limits	• Prone to complicated chemical and microbiological problems • Not all parts and materials may be locally available • Requires expert design and construction • Sludge and possibly effluent require further treatment and/or appropriate discharge

4.3.4.4 Sequencing Batch Reactor

The Sequencing Batch Reactor (SBR) is a different configuration of the conventional activated sludge systems, in which the process can be operated in batches, where the different conditions are all achieved in the same reactor but at different times. The treatment consists of a cycle of five stages: fill, react, settle, draw and idle. During the reaction type, oxygen is added by an aeration system. During this phase, bacteria oxidise the organic matter just as in activated sludge systems. Thereafter, aeration is stopped to allow the sludge to settle. In the next step, the water and the sludge are separated by decantation and the clear layer (supernatant) is discharged from the reaction chamber.

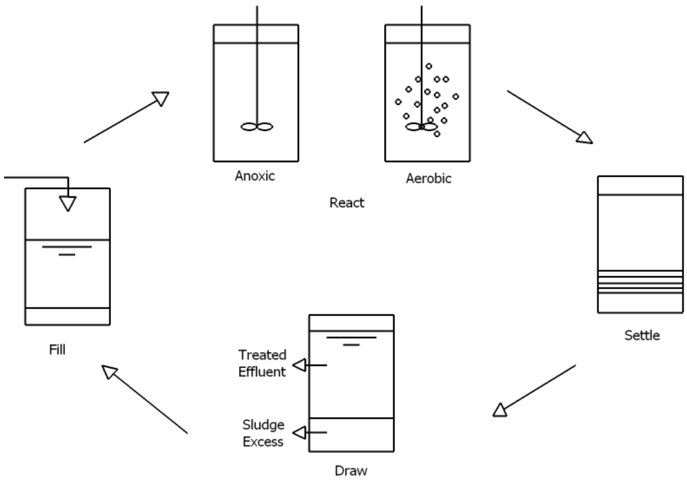


Figure 20 – Schematic diagram of SBR

At least two tanks are needed for the batch mode of operation as continuous influent needs to be stored during the operation phase. Small systems may apply only one tank. In this case, the influent must either be retained in a pond or continuously discharged to the bottom of the tank in order not to disturb the settling, draw and idle phases. SBRs are suited to lower flows, because the size of each tank is determined by the volume of wastewater produced during the treatment period in the other tank.

4.3.4.5 Membrane Bio-reactor

Membrane Bioreactors (MBR) are treatment processes, which integrate a perm-selective or semi-permeable membrane with a biological process (JUDD 2011). It is the combination of a membrane process like microfiltration or ultrafiltration with a suspended growth bioreactor, and is now widely used for municipal and industrial wastewater treatment with plant sizes up to 80'000 population equivalents. Due to it being a very technical solution; it needs expert design and skilled workers. Furthermore, it is a costly but efficient treatment possibility. With the MBR technology, it is possible to upgrade old wastewater plants.

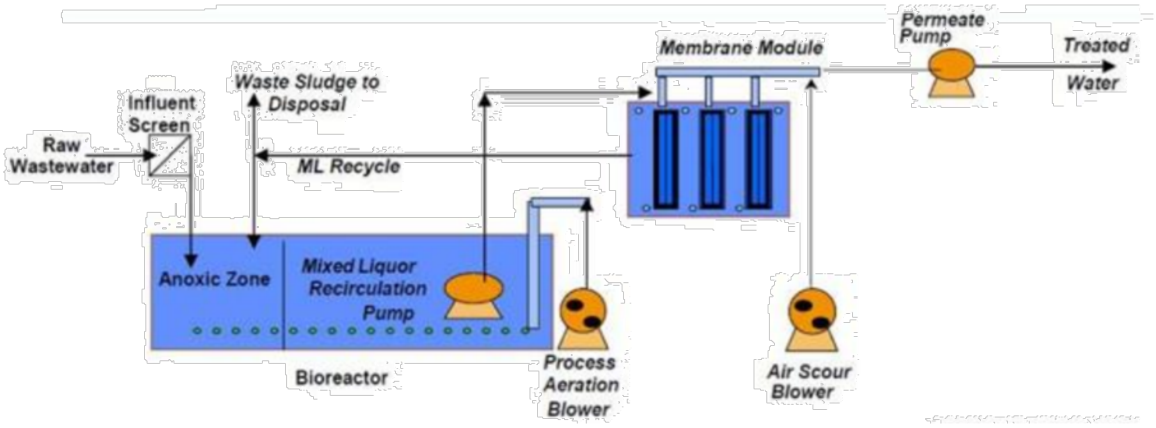


Figure 21 – Schematic diagram of MBR

4.3.4.6 Constructed Wetlands (horizontal flow)

A horizontal subsurface flow constructed wetland is a large gravel and sand-filled basin that is planted with wetland vegetation. As wastewater flows horizontally through the basin, the filter material filters out particles and microorganisms degrade the organics. The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach, and a base for the vegetation. Although facultative and anaerobic bacteria degrade most organics, the vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics as well. The plant roots play an important role in maintaining the permeability of the filter.

The horizontal subsurface flow constructed wetland is a good option where land is cheap and available. Depending on the volume of the water and the corresponding area requirement of the wetland, it can be appropriate for small sections of urban areas, as well as for peri-urban and rural communities. It can also be designed for single households.

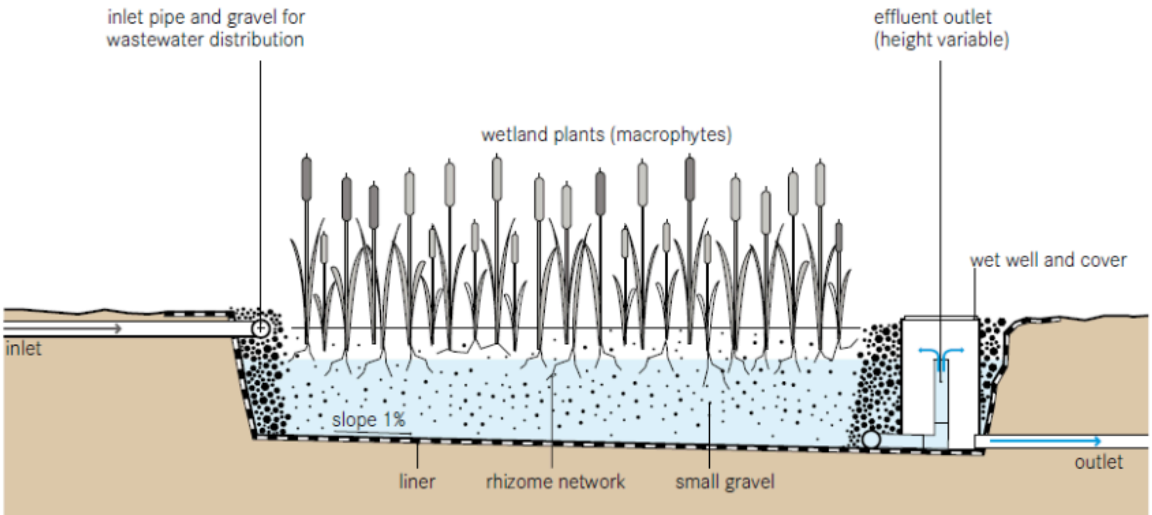


Figure 22 – Schematic diagram of horizontal flow constructed wetlands

Pros	Cons
• High reduction of BOD suspended solids and pathogens • Does do not have the mosquito problems of the Free-Water Surface Constructed Wetland • No electrical energy is required • Low operating costs	• Requires a large land area • Little nutrient removal • Risk of clogging, depending on pre and primary treatment • Long start-up time to work at full capacity • Requires expert design and construction supervision

4.3.4.7 Aerated Ponds

An aerated pond is a large, mixed aerobic reactor. Mechanical aerators provide oxygen and keep the aerobic organisms suspended and mixed with water to achieve a high rate of organic degradation. Increased mixing and aeration from the mechanical units mean that the ponds can be deeper and tolerate much higher organic loads than a maturation pond (see waste stabilization ponds). The increased aeration allows for increased degradation and increased pathogen removal. As well, because oxygen is introduced by the mechanical units and not by light-driven photosynthesis, the ponds can function in more northern climates.

A mechanically aerated pond can efficiently handle concentrated influent and significantly reduce pathogen levels. It is especially important that electricity service is uninterrupted and that replacement parts are available to prevent extended downtimes that may cause the pond to turn anaerobic.

Aerated ponds can be used in both rural and peri-urban environments. They are most appropriate for regions with large areas of inexpensive land located away from homes and businesses. Aerated lagoons can function in a larger range of climates than Waste Stabilization Ponds, and the area requirement is smaller compared to a maturation pond.

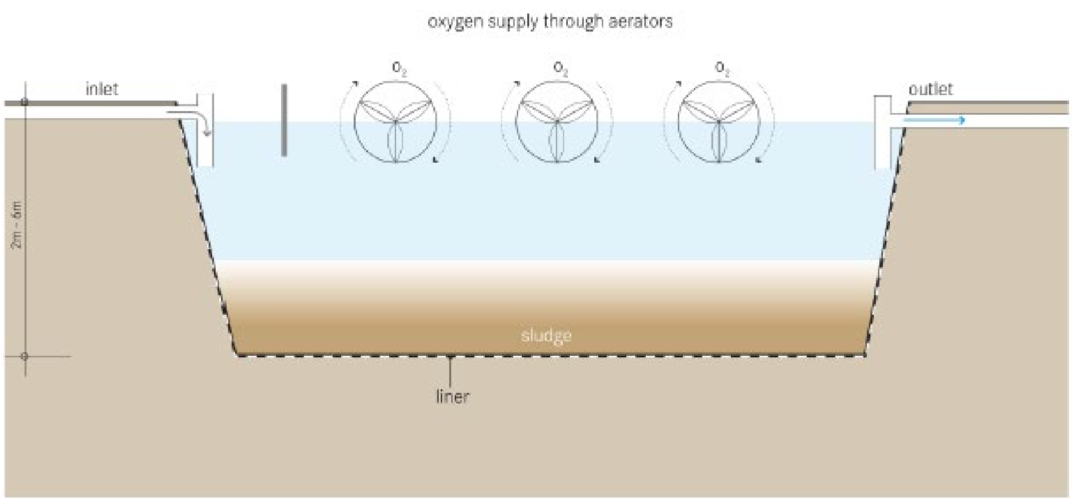


Figure 23 – Schematic diagram of aerated pond

Pros	**Cons**
• Resistant to organic and hydraulic shock loads • High reduction of BOD and pathogens • No real problems with insects or odors if designed and maintained correctly	• Requires a large land area • High energy consumption, a constant source of electricity is required • High capital and operating costs depending on the price of land and of electricity • Requires operation and maintenance by skilled personnel • Not all parts and materials may be locally available • Requires expert design and construction supervision • Sludge and possibly effluent require further treatment and/or appropriate discharge

4.3.5 Tertiary Treatment

4.3.5.1 Chlorination

The destruction, inactivation, or removal of pathogenic microorganisms can be achieved by chemical, physical, or biological means. Due to its low cost, high availability and easy operation, chlorine has historically been the disinfectant of choice for treating wastewater.

Chlorine oxidizes organic matter, including microorganisms and pathogens. Concerns about harmful disinfection by-products (DBP) and chemical safety, however, have increasingly led to chlorination being replaced by alternative disinfection systems, such as (UV) radiation and ozonation (O_3).

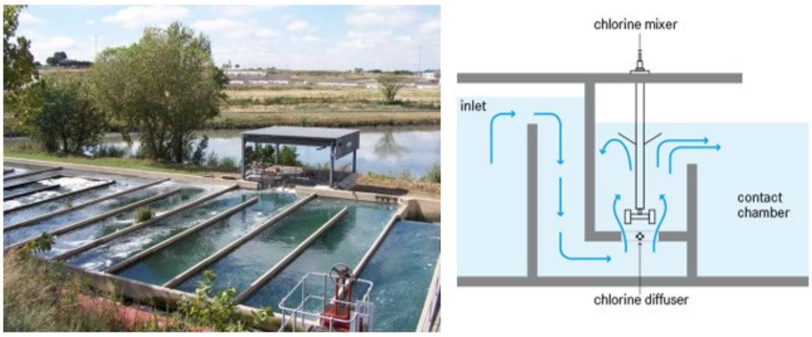


Figure 24 – Chlorination Basin (left), Chlorine dosing and mixer (right)

4.3.5.2 Ozonation

Ozonation is an efficient treatment to reduce the amounts of micropollutants released in the aquatic systems by wastewater treatment plants (MARGOT et al. 2011). Although no residual by-products are generated by ozone itself, some concerns are raised regarding oxidation by-products when water containing both organics and ions, such as bromide, iodide and chlorine ions, are treated with ozonation. A typical ozonation system consists of an ozone generator and a reactor where ozone is bubbled into the water to be treated.

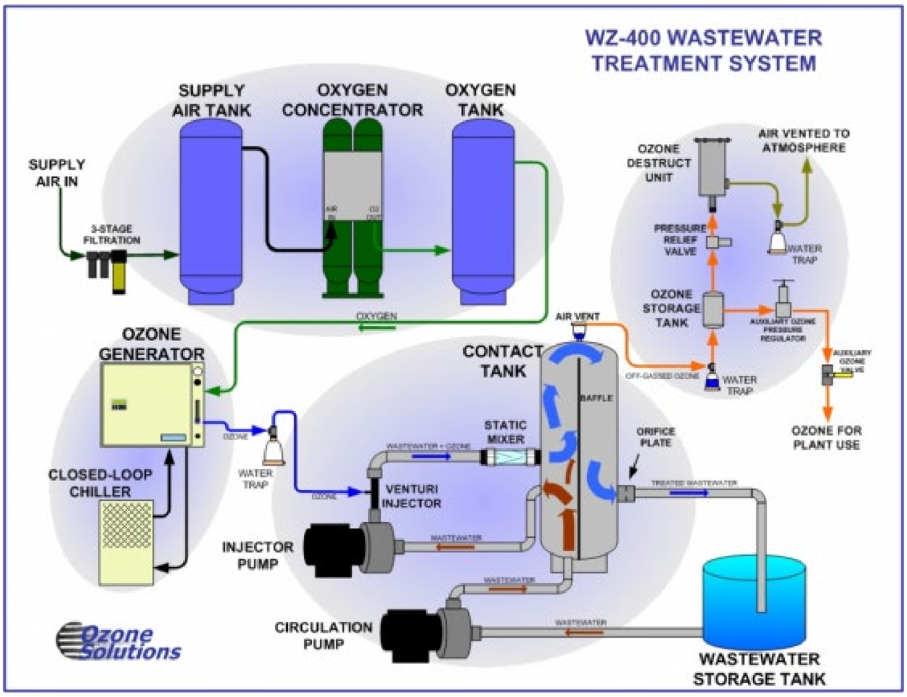


Figure 25 – Schematic diagram of Ozonation

4.3.6 Decentralised Wastewater Treatment System (DEWATS™)

DEWATS™ systems are effective, reliable, cost efficient and custom-made wastewater treatment systems, which are perfectly suited for small to medium-size systems at community level and for individual users like e.g. schools, hospitals, or enterprises. The technical options within DEWATS are based on a modular and partly standardized design. Most common DEWATS modules consist of settler, biogas settlers, anaerobic filters, anaerobic baffled reactors, planted gravel filters, anaerobic ponds, and aerobic ponds. However, wastewater treatment plants do not necessarily include all modules. DEWATS systems can be designed for individual needs.

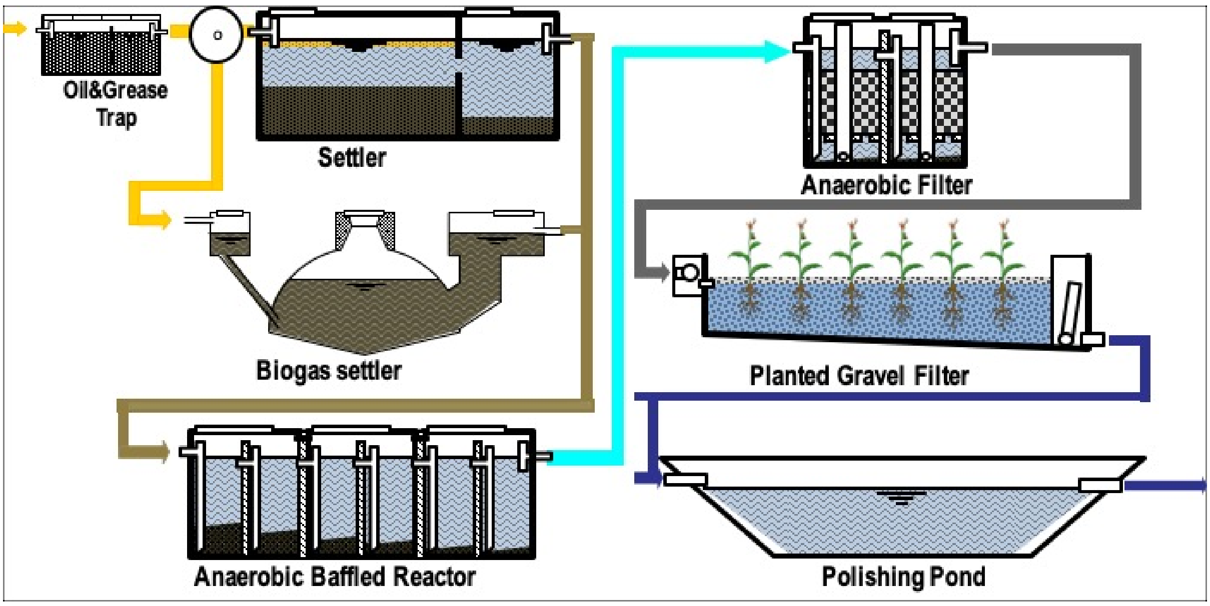


Figure 26 – Schematic diagram of DEWATS modules

Pros	Cons
• Can be applied at various scale (individual, community, cluster) • high treatment efficiency • pleasant landscaping possible • cheap in construction if filter material is easily available • no nuisance of odour • pathogen and nutrient removal • minimal or no energy requirement for treatment process • minimal skill requirement for operation and maintenance • Requires expert design and construction supervision	• high space requirement • requires expert design and construction supervision

4.3.7 Soil Biotechnology (SBT)

In SBT, soil is used as a media for treating the wastewater. SBT is a synthesis process which harnesses the energy, carbon and other elements of the waste and converts them to precious bio-energy products like vegetation, energy, soil, complete bio-fertilizer and water. The SBT is designed to provide the requisite filtration, aeration and bio – chemical processing for removal of toxicity, including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrate, phosphate, suspended solids, colour, odour and bacteria.

In this method, wastewater is pumped or sprayed on the top of the sand bed. The bed consists of cultured soil media, consisting of a layer of boulders, pebbles and sand. The filtering materials are placed over a thick layer of plastic sheets, to prevent seepage loss of wastewater. The wastewater is repeatedly pumped on the top of the soil media using a pipeline network. The treated wastewater, which is collected in the furrows between the soil bund, is finally diverted to a collection well. The collection well also acts as an aeration tank. This water is finally pumped out and used for irrigation. Locally available wild plants are grown on the top of the soil to enhance the treatment process.

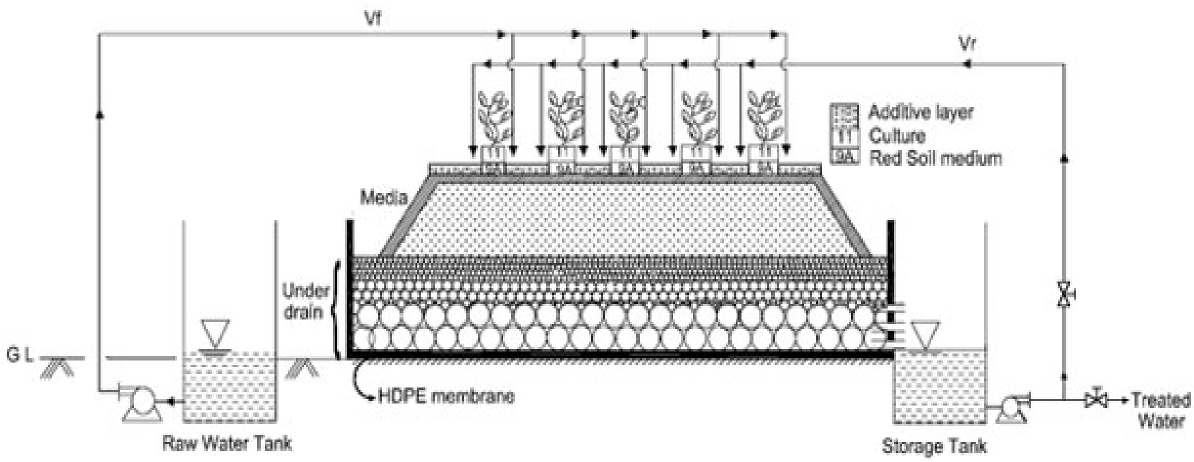


Figure 27 – Schematic diagram of SBT

SBT can be applied for various scales of operation. The wastewater can be treated in batches, semi – continuous as well as continuous mode as per users requirement. The SBT process effectively removes COD, ammonium, nitrates, Suspended Solids, bacteria, colour and odour. In this process, no sludge is produced. SBT offers a bacterial removal of approximately 99.99%, thus ensuring a healthier environment without any side effects. It functions at normal temperatures, is energy efficient and economical. SBT has total size flexibility and can be used in both urban and rural areas. SBT designs can be made inside the house and can be site specific. SBT has a low operation and maintenance cost as the system does not require any chemicals and energy is required only for the purpose of pumping.

5 Faecal Sludge and Septage Management (FSSM)

5.1 Introduction

FSSM refers to the approach towards building a sustainable and environmentally safe infrastructure from containment to end use or disposal of faecal sludge from on-site sanitation systems (OSS). This includes the safe storage, collection, transport, treatment and end-use or disposal of faecal sludge. It is imperative to look at the sanitation market as a value chain where value can be added at each stage. It will, therefore, develop technologies, systems and services which accomplish this at each section of the chain.

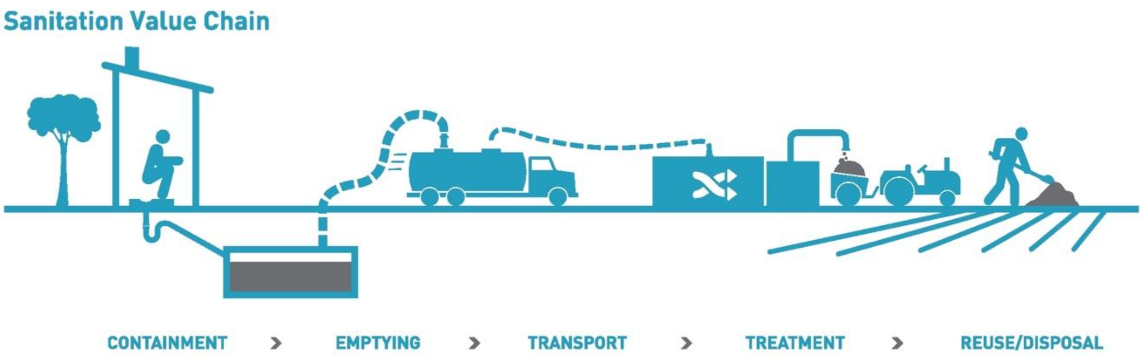


Figure 28 – FSSM Value Chain

Faecal sludge management value chain is concerned with the movement of the faecal sludge/septage from containment to disposal or reuse. FSSM specifically includes the following components,

Containment – any type of latrine or tank which is used to capture and store faecal sludge (only excreta and black/yellow water and wash water is captured and not grey water generated from domestic sources)

Emptying – any type of device used to empty storage devices;

Transport – physically moving the sludge from the storage device to the treatment plant;

Treatment – treating sludge so that it is safe to disposed of or, ideally, reused;

Reuse – regaining value from the sludge by making it's nutritional or calorific content available for agriculture, energy, etc.

5.2 On-site Containment – technology options

5.2.1 Single Pit

It consists of a superstructure and a pit. Faecal matter is deposited into a pit. Urine and water percolate into the soil through the bottom of the pit and wall, while microbial action degrades part of the organic fraction. Pathogenic germs are absorbed to the soil surface. In this way, pathogens can be removed prior to contact with groundwater.

5.2.2 Twin pit for pour flush toilets

It consists of a superstructure (pour flush toilet) connected to two alternating pits (two chambers). The blackwater (and in some cases greywater) is collected in the pits and allowed to slowly infiltrate into the surrounding soil. Only one pit is functional at a time while the other is allowed to rest as the liquid leaches out of the pit. Over time, the solids are sufficiently dewatered and can be manually removed with a shovel. The filled pit can be conveniently emptied after one-and-half years, when most of the pathogens die. The sludge, also called pit humus, can safely be used as manure.

The twin pits for pour flush technology can be designed in various ways; the toilet can be located directly over the pits or at a distance from them. The superstructure can be permanently constructed over both pits, or it can move from side to side depending on which one is in use. No matter how the system is designed, only one pit is used at a time. While one pit is filling, the other full pit is resting.

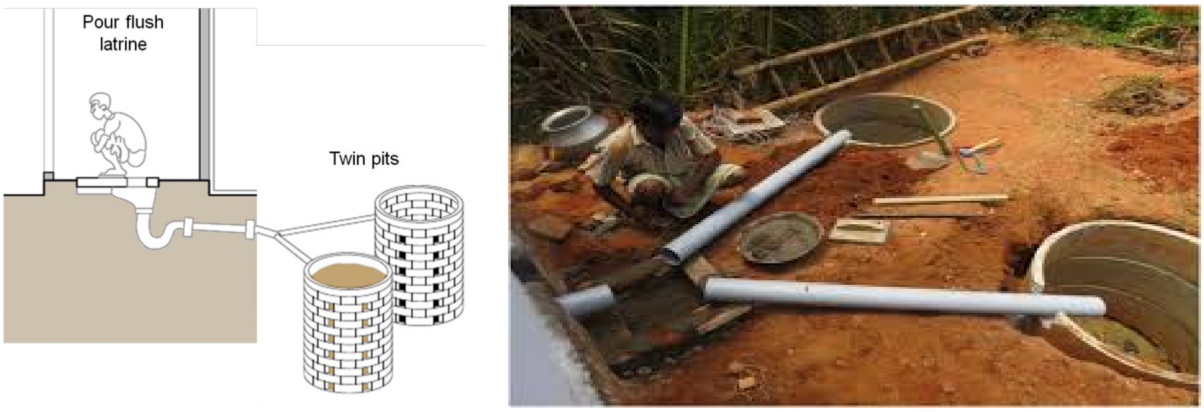


Figure 29 – Twin pits

As liquid leaches from the pit and migrates through the unsaturated soil matrix, pathogenic germs are sorbed onto the soil surface. In this way, pathogens can be removed prior to contact with groundwater. The degree of removal varies with soil type, distance travelled, moisture and other environmental factors. As this is a water-based (wet) technology, the full pits require a longer retention time (two years is recommended) to degrade the material before it can be excavated safely.

Twin pits for pour flush are a permanent technology appropriate for areas where it is not possible to continuously build new pit latrines. If water is available, this technology is appropriate for almost every type of housing density.

Pros	**Cons**
• Because double pits are used alternately; their life is virtually unlimited • Excavation of humus is easier than faecal sludge • Potential for the use of stored faecal material as soil conditioner • Flies and odours are significantly reduced (compared to pits without a water seal) • Can be built and repaired with locally available materials • Low (but variable) capital costs depending on materials; no or low operating costs if self-emptied • Small land area required	• Manual removal of pit humus is required • Clogging is frequent when bulky cleansing materials are used • Higher risk of groundwater contamination due to more leachate than with waterless system

5.2.3 Septic tank

A septic tank is a water-tight, single-storied tank made of concrete, fiberglass, PVC or plastic in which sewage is retained long enough to permit sedimentation and digestion. It is an underground tank that treats sewage by a combination of solids settling and anaerobic digestion. Liquid flows through the tank, and heavy particles sink to the bottom, while scum (mostly oil and grease) floats to the top. Over time, the solids that settle to the bottom are degraded anaerobically. However, the rate of accumulation is faster than the rate of decomposition, and the accumulated sludge and scum must be periodically removed. The effluent from the septic tank must be dispersed by using a Soak Pit or Leach Field or transported to another treatment technology via a Solids-Free Sewer (small bore sewers). Bureau of Indian Standards provides a Code of Practice for Installation of Septic Tanks (IS-2470 Part-1, 1985).

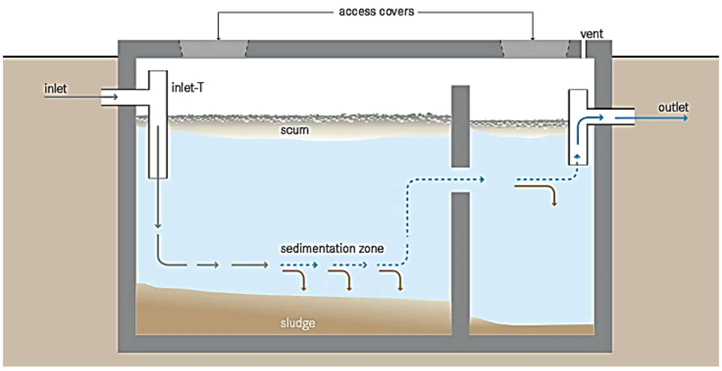


Figure 30 – Septic Tank

The design of a septic tank depends on the number of users, the amount of water used per capita, the average annual temperature, the desludging frequency and the characteristics of the wastewater. The retention time should be 48 hours to achieve moderate treatment. The retention time should be 48 hours to attain moderate treatment.

Table 5 – Recommended size of septic tank upto 20 users

No. of Users	Length (m)	Breadth (m)	Liquid depth (m) (cleaning interval of)	
			2 years	3 years
5	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
15	2.0	0.90	1.3	2.00
20	2.3	1.10	1.3	1.80

Table 6 – Recommended size of septic tank upto 300 users

No. of Users	Length (m)	Breadth (m)	Liquid depth (m) (cleaning interval of)	
			2 years	3 years
50	5.0	2.00	1.0	1.24
100	7.5	2.65	1.0	1.24
150	10.0	3.00	1.0	1.24
200	12.0	3.30	1.0	1.24
300	15.0	4.00	1.0	1.24

This technology is most commonly applied at the household level. Larger, multi-chamber septic tanks can be designed for groups of houses and public buildings (e.g., schools).

A septic tank is appropriate where there is a way of dispersing or transporting the effluent. If septic tanks are used in densely populated areas, onsite infiltration should not be used. Otherwise, the ground will become oversaturated and contaminated, and wastewater may rise up to the surface, posing a serious health risk. Instead, the septic tanks should be connected to some Conveyance technology, through which the effluent is transported to a subsequent Treatment or Disposal site. Even though septic tanks are watertight, it is not recommended to construct them in areas with high groundwater tables or where there is frequent flooding.

Because the septic tank must be regularly desludged, a vacuum truck should be able to access the location. Often, septic tanks are installed in the home, under the kitchen or bathroom, which makes emptying difficult. Septic tanks can be installed in every type of climate, although the efficiency will be lower in colder climates. They are not efficient at removing nutrients and pathogens.

Pros	Cons
• Simple and robust technology • No electrical energy is required • Low operating costs • Long service life • Small land area needed (can be built underground)	• Low reduction in pathogens, solids and organics • Regular desludging must be ensured • Effluent and sludge require further treatment and appropriate discharge

5.2.4 Urine diversion and composting toilet or ECOSAN

ECOSAN is a type of toilet in which human excreta, urine and wash water are separated through specially designed toilet seats unlike the conventional water closets where all these are collected together. Excreta is collected in the chamber constructed below the toilet seat, urine is collected in a drum/pot kept outside the toilet and wash water is diverted to a plant bed raised near the toilet.

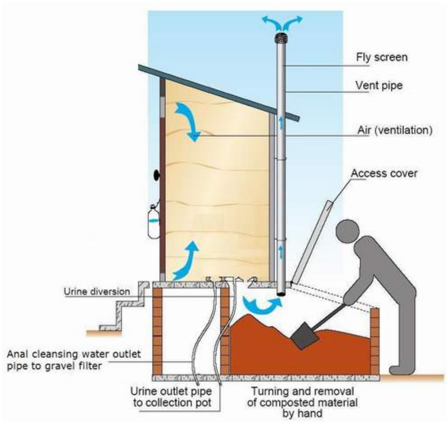


Figure 31 – Urine diversion and composting toilet (Ecosan)

5.2.5 Bio-digester tank system

A bio-digester toilet is an anaerobic multi-compartment tank with inoculum (anaerobic bacteria) which digests organic material biologically. This system converts faecal waste into usable water and gases in an eco-friendly manner.[8]

This technology has been developed by Defense Research and Development Organisation (DRDO) and advocated in SBM. These toilets are widely used for 80% treatment of black water from individual and cluster households or institutional buildings where there is no sewerage network.

[8] *Septage Management: A Practitioner's Guide*, Centre for Science and Environment, New Delhi

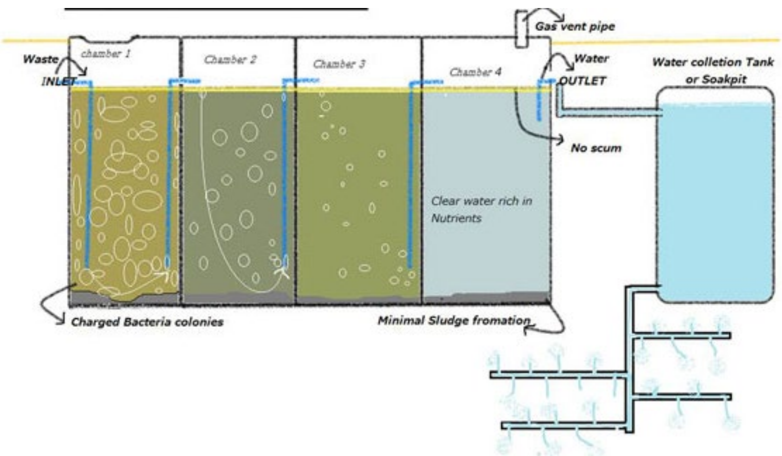


Figure 32 – Bio-digestor tank system

5.2.6 Anaerobic Baffle reactor

An anaerobic baffled reactor (ABR) is mainly a small septic tank (settling compartment) followed by a series of anaerobic tanks (at least three). Most of the solids are removed in the first and largest tank. Effluent from the first tank then flows through baffles and is forced to flow up through activated sludge in the subsequent tanks. Each chamber provides increased removal and digestion of organics: BOD may be reduced by up to 90%. Increasing the number of chambers also improves performance. (Tilley 2008).

The majority of settleable solids are removed in a sedimentation chamber in front of the actual ABR. Small-scale stand-alone units typically have an integrated settling compartment, but primary sedimentation can also take place in a separate Settler or another preceding technology (e.g., existing Septic Tanks). Designs without a settling compartment are of particular interest for (Semi-) Centralized Treatment plants that combine the ABR with other technologies, or where prefabricated, modular units are used.

This technology is easily adaptable and can be applied at the household level, in small neighbourhoods or even in bigger catchment areas. It is most appropriate where a relatively constant amount of blackwater and greywater is generated. A (semi-) centralised ABR is applicable when there is a pre-existing Conveyance technology, such as a Simplified Sewer.

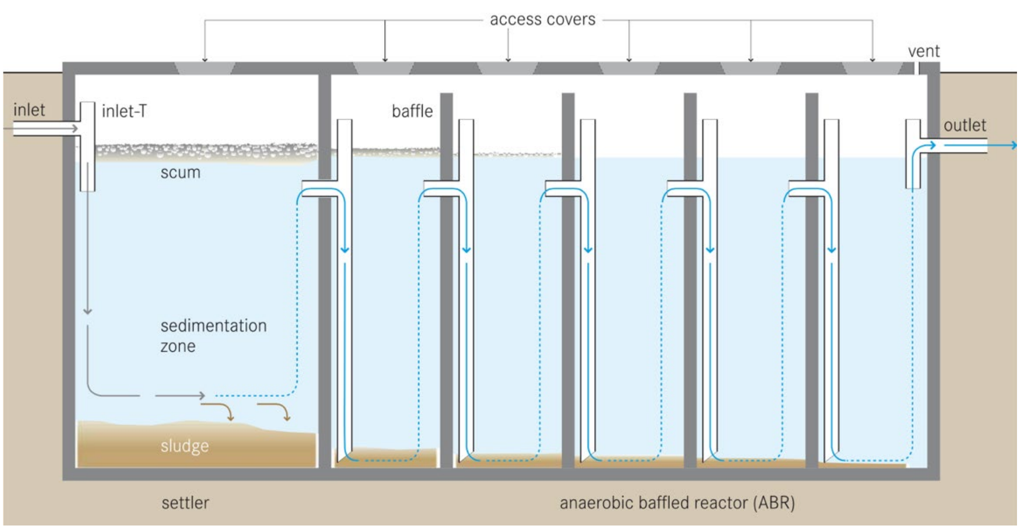


Figure 33 – Schematic diagram of ABR

This technology is suitable for areas where land may be limited since the tank is most commonly installed underground and requires a small area. However, a vacuum truck should be able to access the location because the sludge must be regularly removed (particularly from the settling compartment).

ABRs can be installed in every type of climate, although the efficiency is lower in colder climates. They are not efficient at removing nutrients and pathogens. The effluent usually requires further treatment.

Pros	Cons
• Low cost when divided among members of a housing cluster or small community • Minimum operation and maintenance • Resistant to organic and hydraulic shock loads • Reliable and consistent treatment	• Requires expert design and skilled construction; partial construction work by unskilled labourers • Requires secondary treatment and discharge

5.2.7 Anaerobic up-flow filter

An anaerobic up-flow filter is a fixed-bed biological reactor with one or more filtration chambers in series. As wastewater flows through the filter, particles are trapped, and organic matter is degraded by the active biomass that is attached to the surface of the filter material. With this technology, suspended solids and BOD removal can be as high as 90% but is typically between 50% and 80%. Nitrogen removal is limited and usually does not exceed 15% regarding total nitrogen (TN).

Pre- and primary treatment is essential to remove solids and garbage that may clog the filter. The majority of settleable solids are removed in a sedimentation chamber in front of the anaerobic filter. Small-scale stand-alone units typically have an integrated settling compartment, but primary sedimentation can also take place in a separate Settler or another preceding technology (e.g., existing Septic Tanks). Designs without a settling compartment are of particular interest for (Semi-) Centralized Treatment plants that combine the anaerobic filter with other technologies, such as the Anaerobic Baffled Reactor (ABR).

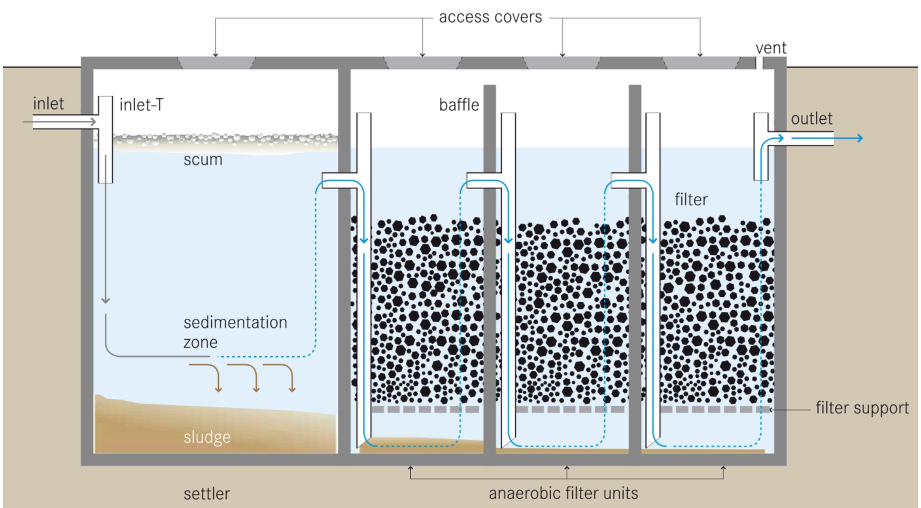


Figure 34 – Schematic diagram of Anaerobic Up-flow Filter

The microbial growth is retained on the stone media, making possible higher loading rates and efficient digestion. Materials commonly used include gravel, crushed rocks or bricks, cinder, pumice, or specially formed plastic pieces, depending on local availability. The connection between the chambers can be designed either with vertical pipes or baffles. Accessibility to all chambers (through access ports) is necessary for maintenance. The tank should be vented to allow for controlled release of odorous and potentially harmful gases. BOD removals of 70% can be expected. The effluent is clear and free from odour.

This technology is easily adaptable and can be applied at the household level, in small neighbourhoods or even in bigger catchment areas. It is most appropriate where a relatively constant amount of blackwater is generated. The anaerobic filter can be used for secondary treatment, to reduce the organic loading rate for a subsequent aerobic treatment step, or for polishing.

This technology is suitable for areas where land may be limited since the tank is most commonly installed underground and requires a small area. Accessibility by vacuum truck is important for desludging.

Pros	Cons
• No electrical energy is required • Low operating costs • Long service life • High reduction of BOD and solids • Low sludge production; the sludge is stabilized • Moderate area requirement (can be built underground)	• Requires expert design and construction • Low reduction of pathogens and nutrients • Effluent and sludge require further treatment and appropriate discharge • Risk of clogging, depending on pre- and primary treatment • Removing and cleaning the clogged filter media is cumbersome

5.3 Emptying and Transport Systems – technology options

5.3.1 Human-powered emptying

Human-powered emptying and transport refer to the different ways in which people can manually empty and/or transport sludge and solid products generated in on-site sanitation facilities. Human-powered emptying of pits, vaults and tanks can be done in one of two ways:

- using buckets and shovels, or
- using a portable, manually operated pump specially designed for sludge (e.g., the Gulper, the Manual Diaphragm Pump or the MAPET).

Manual sludge collection falls into two general categories, namely ‘cartridge containment’ and ‘direct lift’. Cartridge containment and direct lift methods can be practiced safely when operators perform their tasks with the proper equipment following appropriate procedures. For instance, descending into pits as currently practiced in several areas of our country is not safe and legally banned through manual scavenging act.

Dumping of FS directly into the environment rather than discharging at a transfer or treatment site must also be avoided. In addition, local government, can help promote hygienic FS collection by highlighting best practices, imposing restrictions on unsafe practices, and providing incentives such as training, capacity building, and licensing. Formalising the informal sector through training and licensing will drive the demand for improved services, will improve hygiene, and enable business development and job creation.

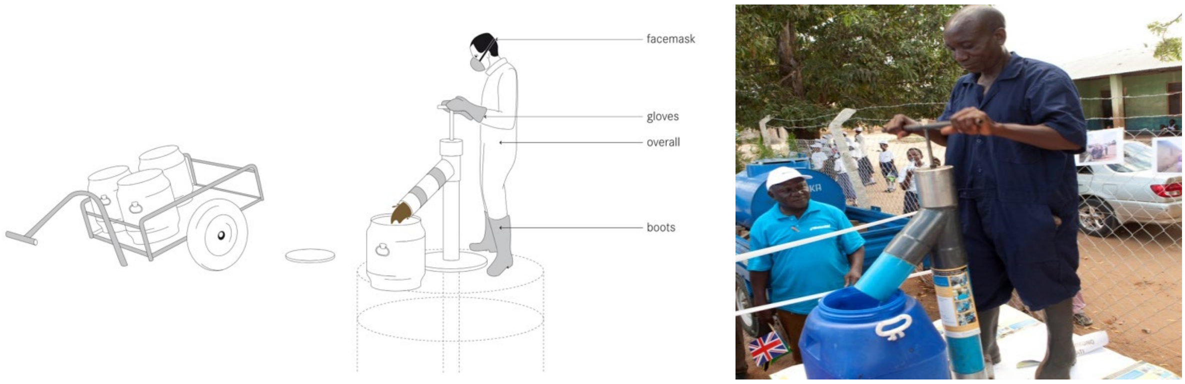


Figure 35 – Human powered emptying of OSS- Gulper

5.3.1.1 Gulper

The Sludge Gulper was developed in 2007 by the London School of Hygiene and Tropical Medicine (LSHTM). It is a low-cost manually driven positive displacement pump that operates along with the same principles as that of direct-action water pumps. The Gulper has a simple design and can be built using locally available materials and fabrication techniques generally common in low-income countries. It consists of a PVC riser pipe containing two stainless steel 'non-return' butterfly valves. One valve, the 'foot' valve, is fixed in place at the bottom of the riser pipe and a second valve, the 'plunger' valve, is connected to a T-handle and puller rod assembly. As the handle is moved up and down, the two valves open and close in series and sludge is lifted the riser pipe to exit the pump via a downward angled spout. The sludge can be collected in barrels, bags or carts, and removed from the site with little danger to the operator. Hand pumps can be locally made with steel rods and valves in a PVC casing A strainer is fitted to the bottom of the riser pipe to prevent non-biodegradable material from entering and blocking the pump.

Table 7 – Technical Details of Gulper

Performance	Purchase/Operating Cost	Challenges
• Suitable for pumping low viscosity sludges • Average flow rates of 30 L/min • Maximum pumping head is dependent on design	• Capital Cost: INR 3000 – INR 90,000 (depending on design) • Operating Cost: Unknown	• Difficulty in accessing toilets with a small superstructure • Clogging at high nonbiodegradable material content • PVC riser pipe prone to cracking • Splashing of sludge between the spout of the pump and the receiving container

5.3.1.2 Diaphragm Pumps

Manually operated diaphragm pumps, are simple low-cost pumps capable of extracting low viscosity FS that contains little non-biodegradable materials. They typically consist of a rigid, disc shaped body clamped to a flexible rubber membrane called a diaphragm. An airtight seal between the diaphragm and the disc forms a cavity. To operate the pump, the diaphragm is alternately pushed and pulled causing it to deform into concave and convex shapes in the same way a rubber plunger is used to unblock a toilet. A strainer and non-returning foot valve fitted to the end of the inlet pipe prevents non-biodegradable material from entering the pump and stops backflow of sludge during operation respectively.

Figure 36 – Manually operated Diaphragm pump

Table 8 – Technical Details of Diaphragm Pump

Performance	Purchase/Operating Cost	Challenges
• Suitable for pumping low viscosity sludges • Average flow rates of 100 L/min • Maximum pumping head of 3.5m – 4.5m	• Capital Cost: INR 20,000 – INR 60,000 (depending on manufacturer and model) • Operating Cost: Unknown	• Clogging at high nonbiodegradable content • Difficult to seal fittings at the pump inlet resulting in entrainment of air • Pumps and spare parts currently not locally available

Pros	Cons
• Potential for local jobs and income generation • Simple hand pumps can be built and repaired with locally available materials • Low capital costs; variable operating costs depending on transport distance • Provides services to areas/communities without sewers	• Spills can happen which could pose potential health risks and --generate offensive smells • Time-consuming: emptying pits out can take several hours/days depending on their size • Garbage in pits may block pipe • Some devices may require specialized repair (welding)

5.3.2 Motorised Emptying and Transport

Motorized emptying and transport refer to a vehicle equipped with a motorised pump and a storage tank for emptying and transporting faecal sludge and urine. Humans are required to operate the pump and manoeuvre the hose, but sludge is not manually lifted or transported. A truck is fitted with a pump which is connected to a hose that is lowered down into a tank (e.g., Septic Tank) or pit, and the sludge is pumped up into the holding tank on the vehicle. This type of design is often referred to as a vacuum truck.

Conventional vacuum tankers are typically fitted with either a relatively low cost, low-volume sliding vane pump or a more expensive liquid ring pump. The former is more appropriate for low-capacity vacuum tankers where high vacuum and low airflow sludge removal techniques are used. Vacuum conveyance techniques work best for removing low-viscosity sludge such as that found in septic tanks.

The type of desludging vehicle or emptier truck that would need to be procured would depend on the volume of septic tanks to be emptied and the number of trips of an emptier truck. Suction-based vacuum trucks or emptier trucks with varying capacities of tanks are available in the market. The capacity of an emptier truck typically varies from 2,000 litres to 20,000 litres. The cost of the truck varies depending upon its capacity. While making the decision regarding the procurement of emptier trucks, ULBs should consider the following factors:

- average road width of the areas from where the septic tanks need to be desludged – road widths and weight constraints
- typical volume of the tanks or vaults that will be serviced;
- characteristics of septage and size of septic tanks: to assess the amount of septage that can be desludged at a time which will consequently affect the number of trips
- distance to the treatment site, access to the site, traffic congestion: to comprehend the number of trips that can be made in a day
- availability and budget
- skill level of the operators.
- Considerations for OPEX – fuel requirements
- Financial budget for emptying services: to assess feasibility before planning for conveyance system.

Figure 38 – Transport options for emptying small volumes of FS/Septage

Figure 37 – Transport options for emptying large volumes of FS/Septage

Depending on the Collection and Storage technology, the sludge can be so dense that it cannot be easily pumped. In these situations, it is necessary to thin the solids with water so that they flow more easily, but this may be inefficient and costly. Garbage and sand make emptying much more difficult and clog the pipe or pump. Multiple truckloads may be required for large septic tanks.

Pros	Cons
• Fast, hygienic and effective sludge removal • Efficient transport possible with large vacuum trucks • Potential for local job creation and income generation • Provides an essential service to non-sewered areas	• Cannot pump thick, dried sludge (must be thinned with water or -manually removed) • Garbage in pits may block hose • Cannot empty deep pits due to limited suction lift • Very high capital costs; variable operating costs depending on use and maintenance • Hiring a vacuum truck may be unaffordable for poor households • Not all parts and materials may be locally available • May have difficulties with access

5.3.3 Transfer stations

Transfer stations or underground holding tanks act as intermediate dumping points for faecal sludge when it cannot be easily transported to a Faecal Sludge or Septage Treatment facility. A vacuum truck is required to empty transfer stations when they are full.

Operators of human-powered or small-scale motorised sludge emptying equipment discharge the sludge at a local transfer station rather than illegally dumping it or travelling to discharge it at a remote treatment or disposal site. When the transfer station is full, a vacuum truck empties the contents and takes the sludge to a suitable treatment facility.

In urban settings, transfer stations have to be carefully located. Otherwise, odours could become a nuisance, especially, if they are not well maintained. A transfer station consists of a parking place for vacuum trucks or sludge carts, a connection point for discharge hoses, and a storage tank. The dumping point should be built low enough to minimise spills when labourers manually empty their sludge carts. Additionally, the transfer station should include a vent, a trash screen to remove large debris (garbage) and a washing facility for vehicles. The holding tank must be well constructed to prevent leaching and surface water infiltration.

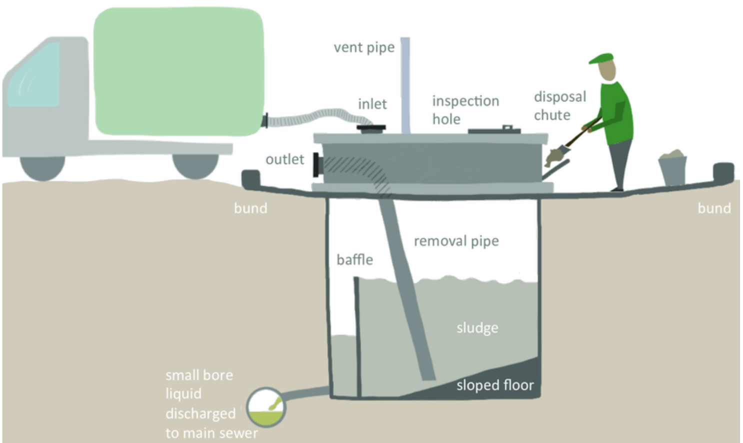


Figure 39 – Fixed type transfer station

Pros	Cons
• Makes sludge transport to the treatment plant more efficient, especially where small-scale service providers with slow vehicles are involved • May reduce the illegal dumping of faecal sludge • Costs can be offset with access permits • Potential for local job creation and income generation	• Requires expert design and construction • Can lead to odors if not properly maintained

5.4 Faecal Sludge and Septage (FSS) Treatment

Faecal sludge comprises all liquid and semi-liquid contents of pits and vaults accumulating in on-site sanitations installations, namely un-sewered public and private latrines or toilets, aqua privies and septic tanks. These liquids are normally several times more concentrated in suspended and dissolved solids than wastewater. Septage comprises of liquid and solid material pumped from a septic tank, cesspool or other primary treatment source.

5.4.1 Basics of Faecal Sludge and Septage Treatment

5.4.1.1 Quantification of Faecal Sludge/Septage

Quantification is necessary for estimating the number of equipment required for providing the service of emptying of septic tanks and transport of the sludge to a treatment facility. It is required to estimate the infrastructure to be provided to co-treat the septage at a existing Sewage Treatment Plant (STP) or to define the capacity of an independent FSS treatment facility. Quantification becomes of utmost importance when financial viability of operationalizing FSSM in a town needs to be understood.

To start with quantification of FSS to be managed, the ULB needs to decide the type of desludging to be practiced. There are two types of desludging practices- (1) on demand desludging and (2) scheduled desludging.

Methods of quantification

Sludge production method

Sludge production method is useful in case of scheduled desludging. This method is based on the number of people and the standard sludge production rate. This is similar to estimating the wastewater production where 80% of the water utilized by the person is taken as quantity of wastewater produced. According to the IS 2470 Code of practice for Installation of Septic Tanks (part 1: Design criteria and construction) 1985, volume of digested sludge in the septic tank is given as 0.00021 m^3/capita/day. The US EPA handbook on Technology Transfer for Septage Treatment and Disposal mentions the average per capita septage generation as 230 Litres/capita/day. It has also been mentioned that his number is highly variable and will change depending on a number of factors discussed in the next session.

Sludge collection method

The sludge collection method needs to be adopted for quantification of FSS in case of demand desludging. In most of the cases of Indian cities, not all the waste which is generated at the household level is usually collected, be it solid of liquid. Hence, sludge collection method is much more reliable estimate of quantification of FSS in a city.

In this method structured interviews need to be conducted with important stakeholders such as desludging operators, ULB official such as sanitary inspectors and households. Depending upon the responses and statistical analysis of the data collected, inferences are drawn to arrive at the quantity of FSS to be managed in a city.

Criteria and considerations for quantification

Seasonal and monthly variations need to be taken into account while quantification. Especially in cities which experience inflow of floating population (due to pilgrimage or tourism) on an annual basis needs to take into consideration the variation and peaking factor.

Peaking factor is necessary to calculate the peak load which the treatment facility might have to handle in a month. The peaking factor in case of FSS can range from 1.5 to 4.

5.4.1.2 Characterization of FSS

The parameters used to characterize the FSS is same as that which are used for sewage and are stated below;

- Solid concentration (TS, TSS, TVS, VSS)
- Chemical Oxygen Demand (COD)
- Biological Oxygen Demand (BOD5)
- Nutrients (TKN, NH3-N, Total P)
- Pathogens (Faecal coliform, Helminth eggs)
- Metals

The slowly biodegradable COD content of faecal sludge is much higher than septage. Hence in order to stabilise the faecal sludge, anaerobic digestion with more retention time is required. Septage has significantly higher amount of particulate non-biodegradable COD. This means septage does not need much stabilisation and COD reduction in septage can be achieved by simply removing the suspended solids from the liquid fraction.

5.4.1.3 Comparison of sludge characteristics and characterization ratios

FSS is highly concentrated in all parameters when compared to sewage. It has been reported in case of some parameters it as up to 68 times more concentrated as compared to sewage.

FSS is stronger than the sewage sludge formed at STP and its characteristics is still different. However, the treatment mechanisms which are used to management of sewage sludge can be tweaked and used for management of FSS.

Ratio (gm/gm)	Public toilets	Septic tanks	Medium strength wastewater
VSS:TSS	0.65-0.68	0.50-0.73	0.60-0.80
$COD:BOD_5$	5.0	1.43-3.0	2.0-2.5
COD:TKN	0.10	1.2-7.8	8-12
BOD_5:TKN	2.2	0.84-2.6	4-6
COD:TP	109	8.0-52	35-45
BOD_5:TP	17	5.6-17.3	15-20

Figure 40 – Characterisation ratios of sludge obtained from different sources

Source: Faecal Sludge Management: System Approach and Implementation

The characterization ratios are important and convey a lot about the constituent of liquid waste and their interdependence. The following table represents characterization ratios for sludge obtained from containment units linked to public toilet, septic tank of household and medium strength wastewater.

The percent of volatile solids to suspended solids tell us about stabilisation of the sludge. Higher the quantity of the VSS means the sludge needs stabilisation. The COD:BOD ratios tell us; how much fraction of the organic solids are easily degradable. The higher ratio indicates higher presence of difficult to digest solids. The organic content to nitrogen ratios also indicates that the organic concentrations are not sufficient for nitrogen removal by denitrification.

Operational factors affecting the sludge characteristics

Local conditions and operational factors which are heavily influenced by habits and behaviour of people impact the FSS characteristics. Following are a few of the operational factors which had an impact on the sludge characteristics;

- Toilet usage- inclusion and exclusion of grey water, use of additives or disposal of solid waste
- Storage duration- frequency of desludging and type of the containment unit
- Infiltration of ground water and exfiltration of wastewater into the ground
- Climate- temperature
- Collection methods- human powered emptying or motorized emptying.

5.4.1.4 FSS Treatment Processes

The ultimate aim of any treatment process or a facility is to ensure protection of human and environmental health and not just to achieve the discharge standards. However, the treatment targets should be appropriate and should be relevant to the local context. Specific treatment objectives when it comes to treatment of FSS are to reduce the water content of the sludge, reduce the number of harmful pathogens, decrease the BOD (reduce organic load present), stabilize and disinfect the liquid and solids. After treatment, the end products can be either discharged to farmland, garden or can be re-used for other purposes such as washing floors, gardening and other similar purposes.

Physical Unit Operations: Treatment methods in which the application of physical forces predominates are known as physical unit operations. Most of these methods are based on physical forces, e.g. screening, filtration, mixing, flocculation, sedimentation, flotation etc.

Screening helps to remove the solid waste from the FSS which can hinder the subsequent processes. Gravity separation is based on the specific gravity of the constituents and helps to remove the solids and fat-oil-grease from the FSS. Filtration processes helps to separate the liquid from the solids using drying bed. Heat drying helps to drive away the moisture.

Chemical Unit Processes: Treatment methods in which removal or conversion of contaminant is brought by addition of chemicals or by other chemical reaction are known as chemical unit processes. Coagulation and flocculation assist the solid liquid separation and accelerates the process. Alkaline stabilisation uses chemicals to stabilise and disinfect the FSS.

Biological Unit Processes: Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes. Biological mechanisms are based on the organic content and their digestibility. Biological processes such as anaerobic and aerobic digestion or composting helps to transform organic waste into nutrients. Anaerobic digestion generates methane gas which can be used as fuel to generate heat or electricity. Co composting of dewatered sludge transforms the organic content of the sludge into compost which is rich in nutrients.

5.4.2 FSS Treatment Chain

There are multiple stages of FSS treatment and each stage has a specific treatment objective. The figure below shows all the stages and treatment mechanisms under each stage and examples of treatment units for that stage.

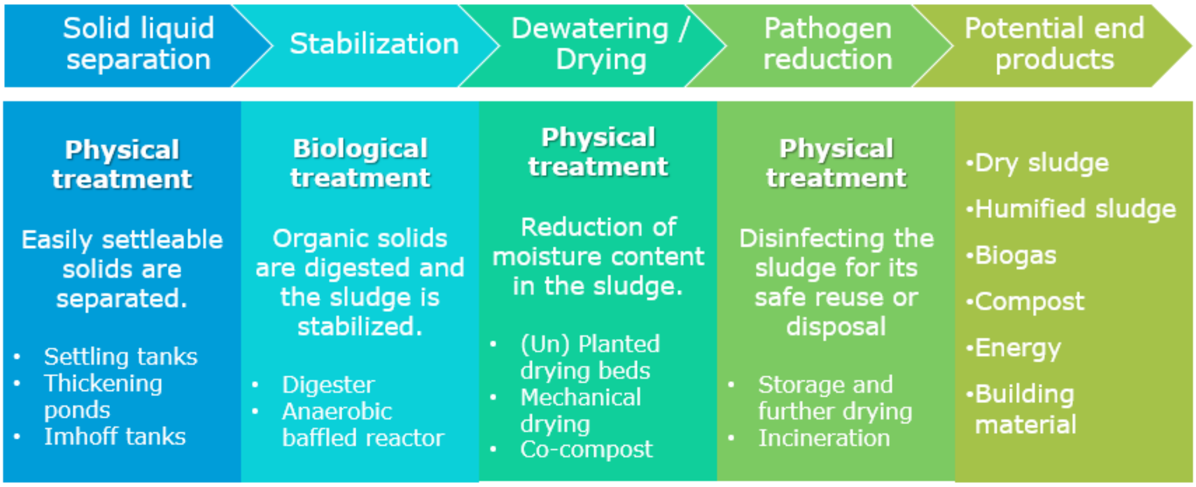


Figure 41 – Faecal Sludge and Septage Treatment Chain

Dewatering

One of the very important treatment objectives of faecal sludge and septage is dewatering. Dewatering helps to reduce the volume of sludge to be handled and treated using other treatment mechanisms, hence it reduces the CAPEX significantly. Separating the solids and liquid stream simplifies the treatment of faecal sludge and septage and helps to optimise the process. Ex. In case of heat drying, dewatering will save a significant amount of energy.

Pathogen removal

The second most important objective is pathogen removal. Pathogen removal is important from the discharge and reuse point of view of the end products. Faecal sludge and septage is known to contain high number of pathogens and hence indiscriminate disposal of it may result in cross contamination of the water resources. Reduction of pathogen is achieved by various ways such as – starvation, predation, exclusions, desiccation, temperature.

Nutrient recovery

Nutrient recovery is a specific treatment objective which is very important when we are intending to use the end products as soil supplements for improving its characteristics. Faecal sludge and septage contain good amount of nutrients. If managed properly, these nutrients can be used as a supplement to synthetic fertilisers in agriculture. However, if not managed properly, it leads to eutrophication of water bodies and further it may lead to contamination of drinking water resources.

Stabilisation

Stabilisation of faecal sludge is also one treatment objective. Faecal sludge contains more organic solids which needs stabilisation before it can be discharged into the environment. Stabilisation reduced the oxygen demand of the liquid fraction of the faecal sludge. The need of stabilisation can be assessed using parameters such as volatile solids, BOD and COD.

5.4.2.1 Criteria for selection of FSS Treatment Processes

Source of FSS needs to be monitored in order to choose the appropriate and maintain the treatment processes after the construction of the treatment facility. Heavy metals cannot be removed using the treatment mechanisms discussed above and hence sludge from the industries should be handled separately. The filtrate from the physical mechanisms such as gravity settling and filtration can be alkaline, which can hamper the treatment of the liquid fraction of the FSS. Monitoring of the end products from the treatment facility is highly recommended so that it keeps a check on the efficiency and operational conditions for preceding treatment mechanisms.

It is important to realize that for the conversion of Faecal Sludge into a product that is safe for end-use or disposal, several processes need to take place. FS typically contains large volumes of water (more than 95%) and hence as the first step of treatment, the easily settleable solids are removed using sedimentation process (dewatering), which can be achieved on its own, or in combination with solid/liquid separation. Depending on the end-goal, further treatment needs could include converting organic matter into a stabilized form and/or pathogen reduction. One of the key elements in designing any particular series of technologies is to keep the final goal in mind. If the final goal is to make a dry product that can be reused in agriculture, then particular care has to be paid to dewatering and pathogen reduction. If the goal is to incinerate the sludge for energy production, then dryness is very important while pathogens do not play a role (outside of worker protection).

Table 9 – Criteria for selection of treatment options

Treatment performance	Local context	O&M requirements	Costs
• Effluent and sludge quality according to national standards	• Characteristics of sludge (dewaterability, concentration, degree of digestion, spreadability) • Quantity and frequency of sludge discharged at the FSTP • Climate • Land availability and cost • Interest in end-use (fertilizer, forage, biogas, compost, fuel)	• Skills needed for operation, maintenance and monitoring available locally • Spare parts available locally	• Investment costs covered (land, infrastructure, human resources, capacity building) • O&M costs covered • Affordability for households

Treatment performance

The primary criteria are that the treatment facility should be able to produce end products meeting the standards of discharge/ end-use.

Local context

Most important criteria are the local context. The characteristics of the sludge and its characterisation ratios determine the degree of stabilisation and dewaterability etc. The frequency of desludging affects the quality of the sludge. Hence, it the frequency of the desludging is high, there is a possibility of having faecal sludge. In that case, stabilisation of sludge becomes important.

Climate plays an important role in case of all-natural treatment mechanisms such as evaporation, evapotranspiration and stabilisation.

Land availability and its cost of acquisition must also be considered before finalising the treatment mechanisms. In cases where the land is not available and acquisition of it is costly or time consuming, it is advisable to go for treatment mechanisms demanding less area.

If there is interest in the use of end products of treatment then treatment mechanisms suitable to produce those end products in demand should be chosen. Ex. In cases where there is a demand for biochar, pyrolysis will be suitable treatment mechanisms for pathogen reduction.

O&M requirement

Availability of resources such as skilled persons, spares etc at local level is very important. In absence of local availability of the resources, no treatment technology is going to economically viable in spite of it producing very high-quality end product.

Costs

The CAPEX and OPEX of the technology are also one of the criteria which is thought as the only criteria. Affordability of the complete project to the ULB or the end beneficiaries such as households should also be checked.

5.4.3 FSS Treatment – technology options

5.4.3.1 Deep Row Entrenchment

Deep row entrenchment consists of digging deep trenches, filling them with sludge and covering them with soil. Trees are then planted on top, which benefit from the organic matter and nutrients that are slowly released from the FS. In areas where there is adequate land available, deep row entrenchment can present a solution that is simple, low cost, has limited O&M issues and produces no visible or olfactory nuisances. Benefits are also gained from the increased production of trees. However, the availability of land is a major constraint with deep row entrenchment, as is the distance/depth to clean groundwater bodies. Deep row entrenchment is considered most feasible in areas where the water supply is not directly obtained from the groundwater source and where sufficient land is available, which means the sludge would have to be transportable to rural and peri-urban areas. In many countries' legislation is still lacking for this option.

Figure 42 – Deep row entrenchment

<u>Advantages and Constraints</u>

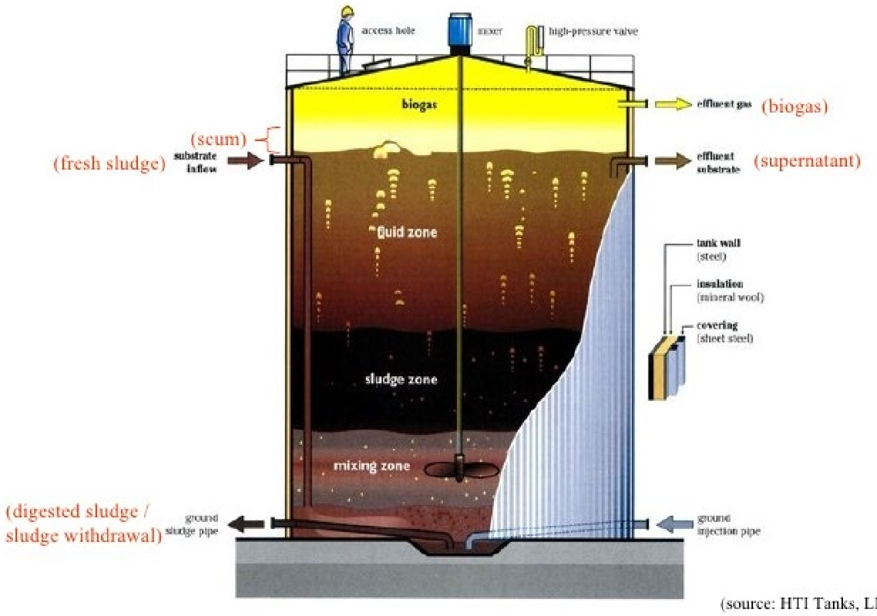
The main advantage of deep row entrenchment is that very little is needed for it: no expensive infrastructure or pumps that are very susceptible to poor maintenance. In addition, growing trees has many benefits such as extra CO2 fixation, erosion protection, or potential economic benefits.

Constraints are that sufficient land has to be available in an area with a low enough groundwater table and, moreover, legislation still needs to catch up in many countries to allow for this technology.

5.4.3.2 Anaerobic digestors

Anaerobic digestors treat organic waste in airtight chambers to ensure anaerobic conditions. Anaerobic digestion has been widely applied in centralized wastewater treatment facilities for the digestion of primary sludge and waste activated sludge, typically with plug flow (PFR) or continuously stirred reactors (CSTRs). The main design parameters for anaerobic digesters are the hydraulic retention time (HRT), the temperature and the loading pattern. Operating conditions that play an important role in the design and operation of anaerobic digesters include:

- solids retention time (SRT);
- HRT;
- temperature;
- alkalinity;
- pH;
- toxic / inhibiting substances; and
- bioavailability of nutrients and trace elements.



(source: HTI Tanks, LLC)

Figure 43 – Schematic diagram of Anaerobic Digestor

Advantages and Constraints

Anaerobic digestion has the potential to produce biogas while stabilising FS, reducing sludge volume and odours. However, operation and maintenance (O&M) of anaerobic digesters requires a relatively high level of skilled operation. Inhibition of digestion needs to be considered due to the inconsistent nature of FS, and also detergents and heavy metals should be addressed at the household level

5.4.3.3 Imhoff Tanks

An Imhoff tank is a compact sized tank that combines the effect of a settler and an anaerobic digestion system in one. It is a compact system which is well-known for wastewater treatment and has been implemented in Indonesia for FS treatment. Imhoff tanks are most often used as a primary treatment technology in wastewater treatment where it serves as a solid-liquid separation system including partial digestion for the settled sludge. The Imhoff tank is a high raised tank (up to nine meters for wastewater sludge) where sludge settles at the bottom and biogas produced by the anaerobic digestion process rises to the top. The settling compartment has inclined walls (45° or more) and a slot at the bottom, which allows the sludge to slide down to the center into the digestion compartment. The gas transports sludge particles to the water surface, creating a scum layer. T-shaped pipes or baffles are used at the inlet and the outlet to reduce velocity and prevent scum from leaving the system. The sludge accumulates in the sludge digestion chamber, and is compacted and partially stabilized through anaerobic digestion.

Advantages and Constraints

The main advantages of Imhoff tanks compared to settling-thickening tanks are the small land requirement, the possibility of operating only one tank, and the physical separation between the

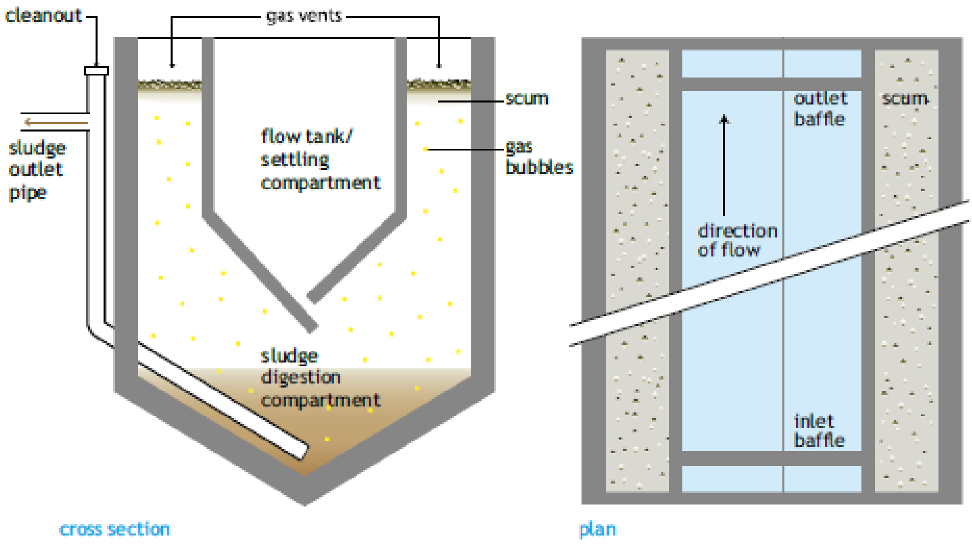


Figure 44 – Schematic diagram of Imhoff Tank

settled sludge and the liquid fraction. The main constraints compared to settling thickening tanks are the increased operational complexity, slightly higher costs as the Imhoff tanks require an additional elevation to accommodate the inclined baffles, and the risk of damage to the sludge draw-off pipe in case of an inadequate draw-off frequency. Operation and maintenance of an Imhoff system is not as complex as some technologies, but it requires skilled operators. Cleaning of flow paths, the sides of the tank as well as the removal of scum is very important.

5.4.3.4 Settling / Thickening Tanks

Settling-thickening tanks are used to achieve separation of the liquid and solid fractions of faecal sludge (FS). Settling-thickening tanks for FS treatment are rectangular tanks, where FS is discharged into an inlet at the top of one side and the supernatant exits through an outlet situated at the opposite

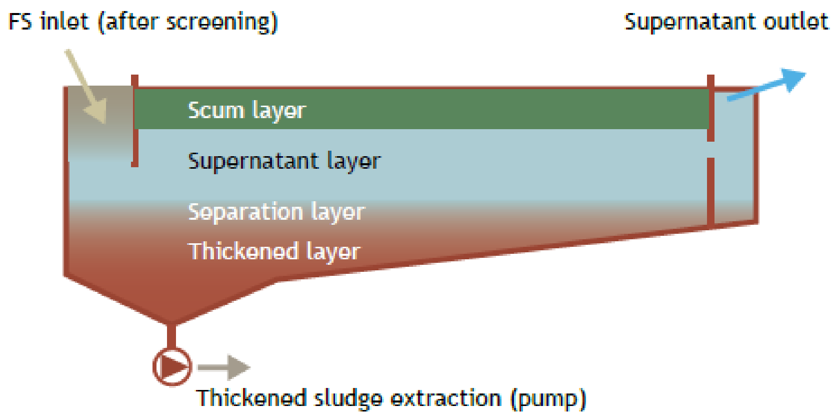


Figure 45 – Representative diagram of Settling – Thickening Tank

side, while settled solids are retained at the bottom of the tank, and scum floats on the surface. During the retention time, the heavier particles settle out and thicken at the bottom of the tank as a result of gravitational forces. Lighter particles, such as fats, oils and grease, float to the top of the tank. As solids are collected at the bottom of the tank, the liquid supernatant is discharged through the outlet. Quiescent hydraulic flows are required, as the designed rates of settling, thickening and flotation will not occur with turbulent flows. Baffles can be used to help avoid turbulence at the inflow, and to separate the scum and thickened sludge layers from the supernatant.

5.4.3.5 Unplanted Sludge Drying Beds

Unplanted sludge drying beds are shallow filters filled with sand and gravel with an under-drain at the bottom to collect leachate. Sludge is discharged onto the surface for dewatering. The drying process in a drying bed is based on drainage of liquid through the sand and gravel to the bottom of the bed, and evaporation of water from the surface of the sludge to the air. Depending on the faecal sludge (FS) characteristics, a variable fraction of approximately 50-80% of the sludge volume drains off as a liquid (or leachate), which needs to be collected and treated prior to discharge. After reaching the desired dryness, the sludge is removed from the bed manually or mechanically. Further processing for stabilization and pathogen reduction may be required depending on the intended end-use option.

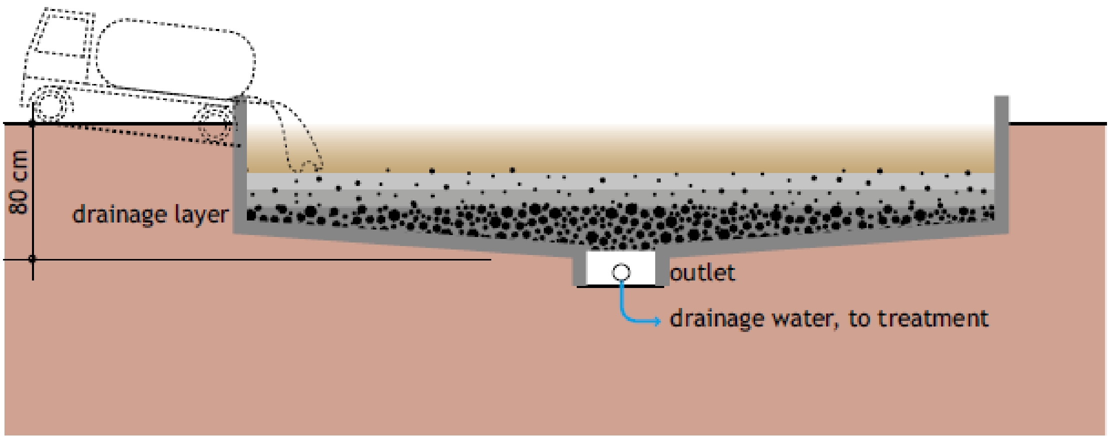


Figure 46 – Schematic diagram of Unplanted Drying Beds

When considering the installation of a drying bed, the ease of operation and low cost needs to be considered against the relatively large footprint and odor potential.

5.4.3.6 Planted Drying Beds

Planted drying beds (PDBs), also sometimes referred to as planted dewatering beds, vertical-flow constructed wetlands and sludge drying reed beds, are beds of porous media (e.g. sand and gravel) that are planted with emergent macrophytes. PDBs are loaded with layers of sludge that are subsequently dewatered and stabilized through multiple physical and biological mechanisms. The dewatering, organic stabilization and mineralization performance of the PDB depends on a variety of factors such as the media type and size, the type of plants, the maturity of the beds, climatic factors, and the sludge characteristics, as well as operational factors such as the hydraulic loading rate (HLR), the solids loading rate (SLR), and the loading frequency.

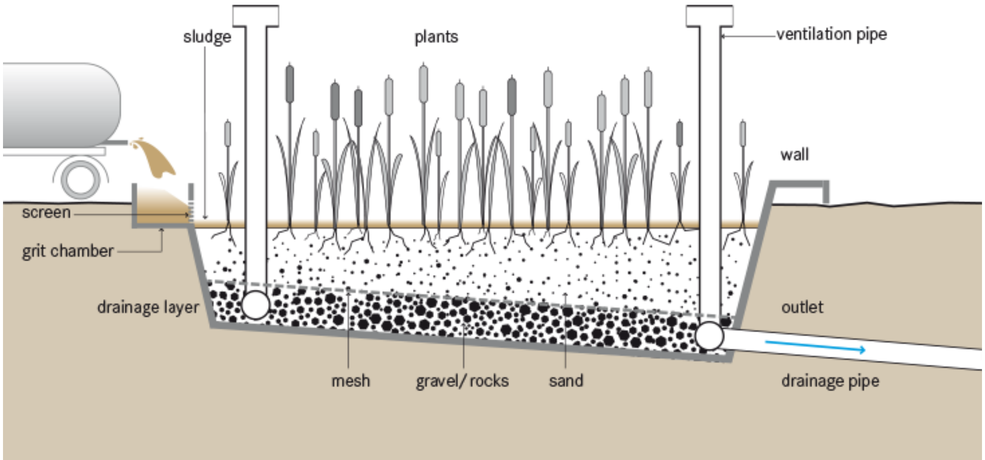


Figure 47 – Schematic diagram of Planted Drying Beds

5.4.3.7 Mechanical Sludge Treatment

Mechanical dewatering or thickening can be carried out prior to, or following other treatment steps. Dewatering and thickening are important for reducing the volume of sludge that needs to be further treated or managed. After the sludge thickening process, additional reduction of the water content is often necessary and this can be done either naturally or by machine processes such as centrifugation or pressing. Four technologies that are widely used for dewatering WWTP sludge are the belt filter, the centrifuge, the frame filter press, and the screw press.

Centrifuge

Centrifuge technology dries the FS as it is squeezed outwards on the surface of a cylinder rotating around its horizontal axis, due to the centrifugal force. The flocculated sludge is injected into the middle of this cylinder, and the particles are pushed outward against the surface. An Archimedean

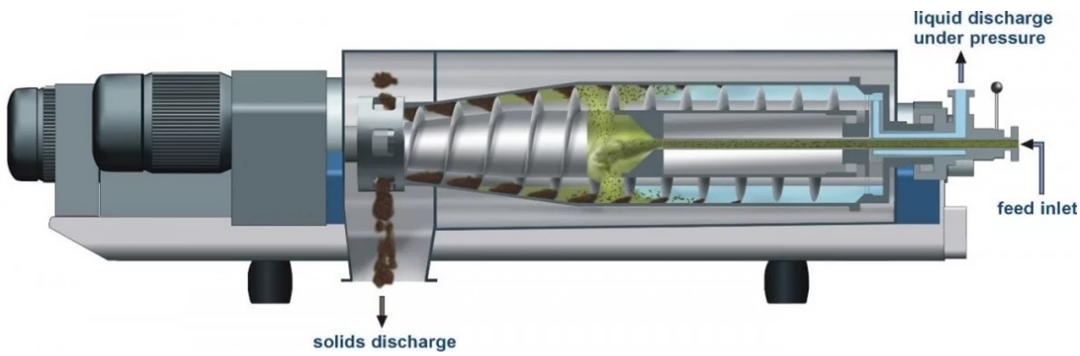


Figure 48 – Schematic diagram of Centrifuge

screw transports the released liquid to the side where the sludge entered, while another transports the sludge to the other end. The main disadvantage of the centrifuge is the high energy requirements.

Screw Press

A screw press consists of a rotational screw placed in a perforated cylinder. The sludge is loaded at one end, it is pressurised due to a diminishing distance between the screw and the cylinder, and the liquid that is squeezed out is removed through the pores in the cylinder. The dewatered sludge is discharged at the other end. Screw presses provide dewatering at relatively low equipment and

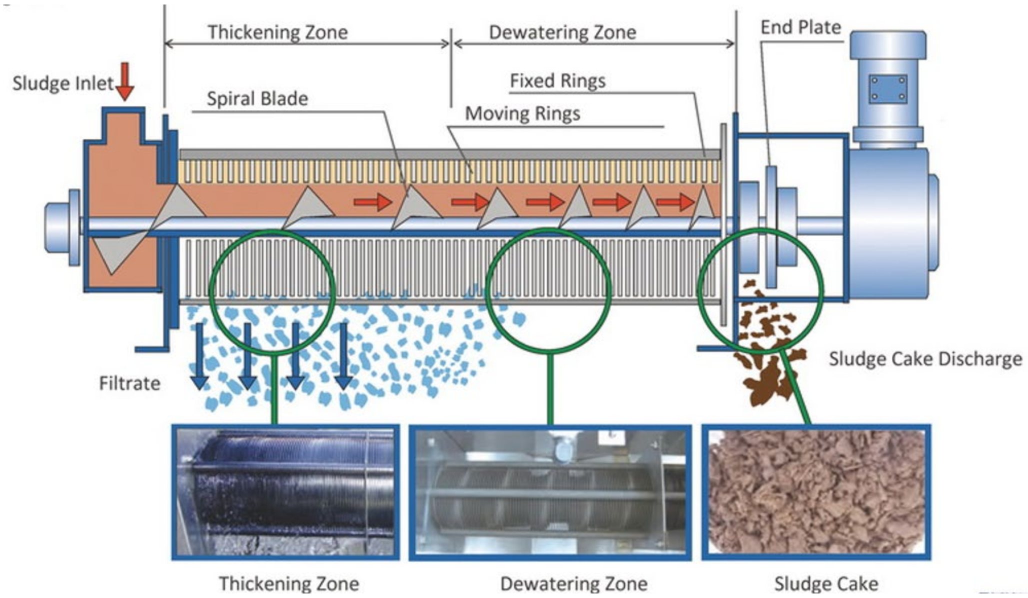


Figure 49 – Schematic diagram of of Screw Press

operational costs, and minimal maintenance skills are required. However, the dewatering is comparatively lower than other mechanical dewatering technologies.

Belt Press

Belt filter press: This allows the water to be squeezed out of the sludge as it is compressed between two belts. The main disadvantages of a belt filter press compared to other mechanical dewatering techniques are the need for skilled maintenance and the difficulty in controlling odours. The system consists of:

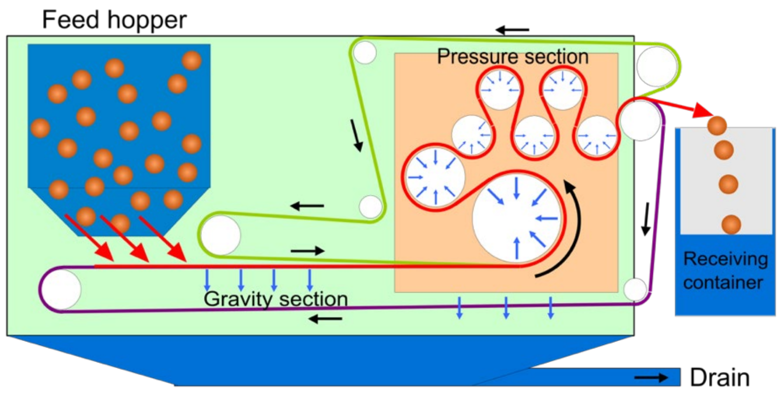


Figure 50 – Schematic diagram of Belt Press

- A gravity drainage zone where the flocculated sludge is deposited and conveyed on a porous and mobile belt;

- A compression zone where a second belt is applied on the upper layer of the sludge, and compresses it to a pressure that can reach 7 bars; and
- A zone where the belts are separated and the dewatered sludge is released.

Frame-Filter Press

Frame-filter press system consists of porous vertical frames fixed in two walls that are positioned in front one of the other to create a chamber. This is a batch process in which the sludge is filled into the chamber at high pressure (up to 15 bars resulting in the leachate being released through the porous frames and the dewatered sludge being released through the opening of the lower wall).

5.4.3.8 Sludge Incineration

Incineration of sludge is a form of disposal which involves the burning of sludge at temperatures between 850-900°C. It does not typically take advantage of the potential for resource recovery, however, energy can be captured from the incineration of sludge, for example in cement kilns. The ash that is produced from incineration could potentially be used, for example as a cover material for urine diversion dry toilets or in construction, or it can be disposed of in landfill sites. Sludge needs to be dewatered prior to combustion, but stabilization treatment is not necessary as it decreases the volatile content of the sludge. Commonly used incineration systems are multiple-hearth incineration, fluidized-bed incineration and co-incineration with municipal solid waste.

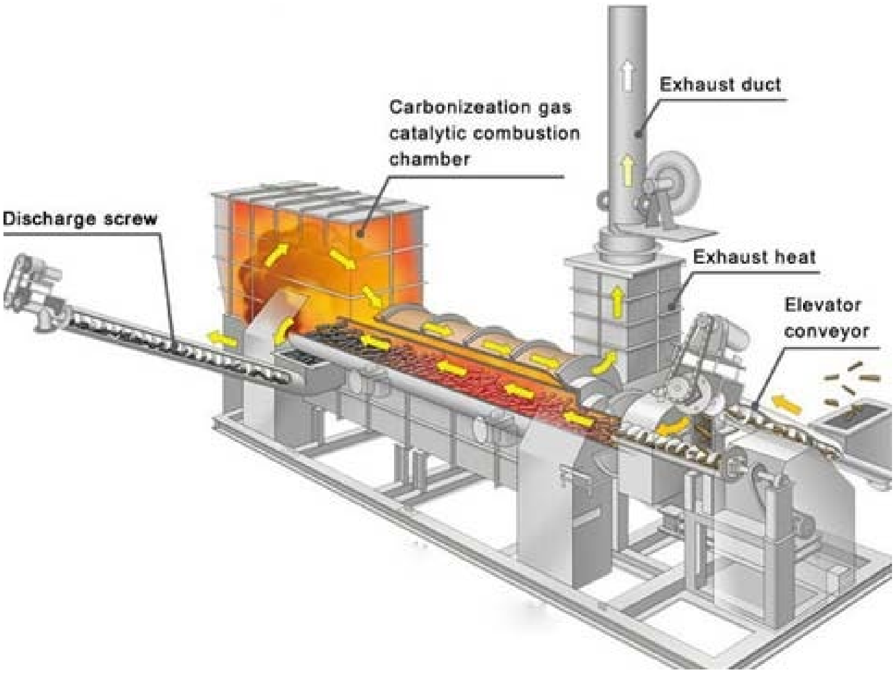


Figure 51 – Schematic diagram of Sludge Incineration Plant

Advantages and Constraints

Disadvantages include: the potential emission of pollutants; the need for highly skilled operating and maintenance staff, high capital and O&M costs; and residual ashes. Advantages are that the sludge volume is substantially reduced and all pathogens are removed.

5.4.3.9 Thermal Drying and Pelletising – LaDaPa System

These systems require preliminary dewatering if used for sludge that is high in water content. In direct thermal driers, the hot air or gases are mixed with the dewatered sludge, as they pass through it, or are transported with it. In indirect thermal driers, a heat exchanger is used, which allows the heat convection to the sludge. In this case, the heat carrying media is often steam or oil, and does not come in direct contact with the sludge, which reduces the operational need to separate the sludge from the heat carrier. In both cases, the vapor produced by the evaporated water needs to be collected and transported out of the dryer. Gas treatment can be an issue depending on environmental requirements and the odours produced. Indirect thermal dryers produce less contaminated vapor.

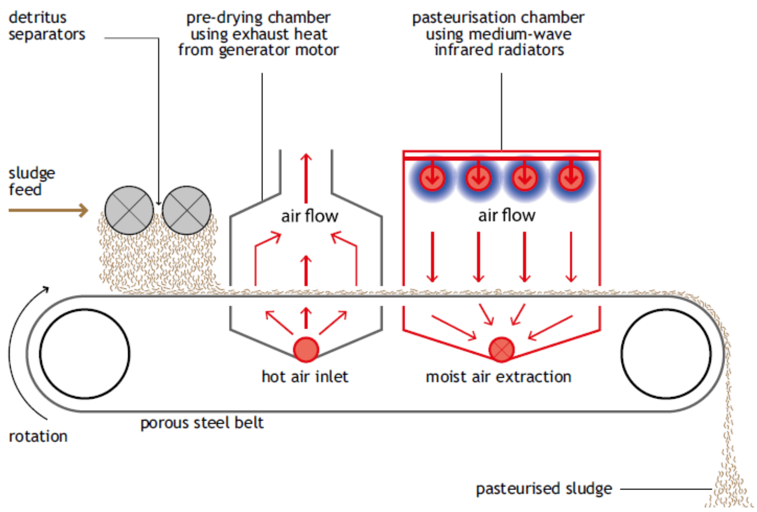


Figure 52 – Schematic diagram of LaDaPa System

Advantages and Constrains

Thermal drying results in a significant reduction in volume as well as pathogen content. Dried sludge is easy to handle and to market, and can be used in agriculture. The main constraints are the expense, high energy requirements, the potential risks of fire or explosion due to the gas and dust in the system, and the high maintenance requirements.

Pelletizing combines mechanical dewatering and thermal drying technologies. The dried pellets can then be used as an energy source or soil conditioner, and are relatively easy to transport and to market.

5.4.3.10 Geobags

Geobags are of high-strength, permeable, specially engineered textiles designed for containment and dewatering of high moisture content sludge and sediment. They are available in a variety of sizes, depending on your volume and space requirements.

Advantages and Constraints

The advantage is as high flow rate allows residual materials to dewater, whilst containing solids and Custom fabricated with seaming techniques that withstand pressure during pumping operations. The main constraint is it has to be disposed of after first use and can't be reuse it for second.

Figure 53 - Geobags

5.4.3.11 Co-treatment in STP

One of the approaches for Faecal Sludge and Septage (FSS) treatment is co-treatment with sewer-based wastewater treatment technologies. However, appropriate treatment facilities are needed at sewage treatment plants to receive, pre-treat, and distribute the septage into the appropriate process units. Septage which may be considered a high strength wastewater, can be either dumped into an upstream sewer or added directly into various unit processes in a sewage treatment plant. The considerably higher solids content of faecal sludge may lead to severe operational problems such as solids deposition and clogging of sewer pipes. This is mostly because the diameter and slope of sewers are designed for the transport of municipal wastewater typically containing 250 to 600 mg TSS/L rather than the 12,000 to 52,500 mg TSS/L present in FS. Hence, the first step in designing a co-treatment system includes determining how the FS will be transported to the treatment facility and discharged into the influent stream.

The typical components of septage receiving facility at STP includes dumping station, screens, grit removal, equalization tank and odor control unit.

5.4.3.12 Co-composting of FS

Composting is a biological process that involves microorganisms that decompose organic matter under controlled predominantly aerobic conditions. The resulting end product is stabilized organic matter that can be used as a soil conditioner. It also contains nutrients which can have a benefit as a long-term organic fertilizer. Co-composting of FS with MSW is best implemented with sludge that has undergone dewatering (e.g. settling-thickening tanks or drying beds).

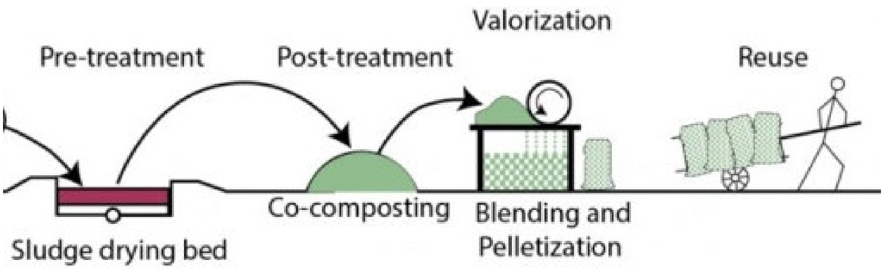


Figure 54 – Schematic diagram of Co-composting

Advantages and Constraints

The main advantage of co-composting is formed by the thermophilic conditions and the resulting pathogen inactivation. The output of co-composting is a good soil conditioner which provides potential for income generation depending on the demand for compost. However, operating a co-

composting plant and generating a safe product with value requires technical and managerial skills, which can be limiting if not available.

5.4.4 Disposal and Re-use of treated septage

There are numerous usages of treated septage. The discharged treated water can be disposed in lakes, river or open farm fields. However, it is important to check the parameters of the treated discharged water before disposal. The disposed water in the farm fields is actually a re-use of the treated water. This helps in improving the yield of the soil as the treated water still contains nitrogen and relevant required nutrients for crops to grow. However, this treated water should be released only in those farmlands which do not grow vegetables or edible crops. The other uses of this water could be for use in gardening or flushing.

The treated sludge is converted into cakes or pellets that are then, packaged or sold loose as manure. This manure is rich in nutrients otherwise nowadays absent in the natural land. As these manures are free from any manufactured chemicals, it is organic in nature and biochemically not harmful to the yield crop.

5.4.5 Approaches for FS/Septage Treatment

The existing approaches in the treatment of faecal sludge can be classified into the following types:

Clustering: This refers to clustering nearby towns and providing them with a common faecal sludge treatment plant. The towns should be at a distance that is economically viable for the desludging operators to serve. A stakeholder consultation with the desludging operators and the municipal authorities of the town can help arrive at the feasible location for the treatment plant.

Co-treatment: This method uses the existing sewage treatment infrastructure to treat faecal sludge. It can be done in the following ways:

- Adding the faecal sludge at the headworks of the sewage treatment plant in a controlled manner. Process the septage along with the bio-solids (i.e. sludge) produced during the wastewater treatment process.
- Separate the septage liquid from the septage solids and process each separately: liquid with the domestic wastewater and solids with the STP biosolids.

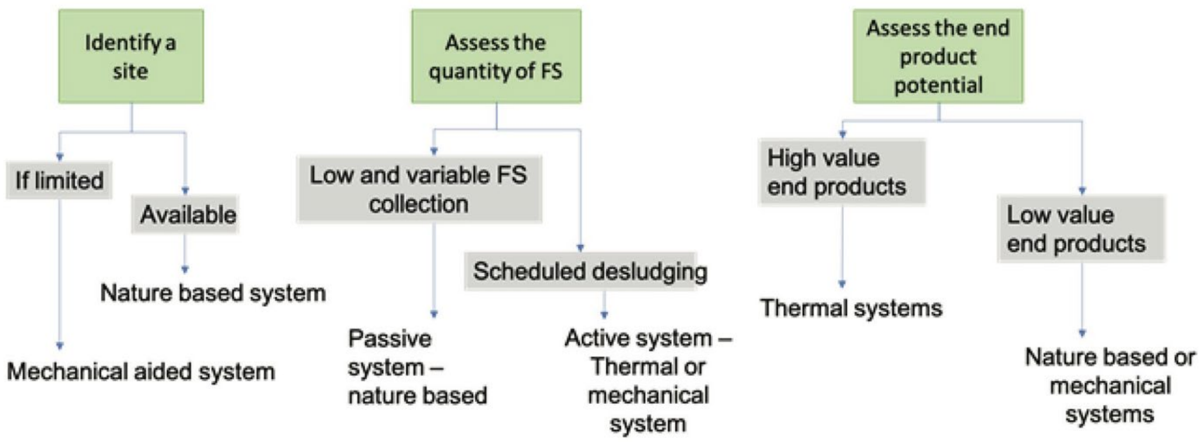


Figure 55 – Criteria for selection of FS treatment approach/technology

The present utilisation of the sewage treatment plant (STP) in terms of hydraulic load (quantity of sewage treated) and organic load (quantity of biodegradable components in the sewage) should be tested to determine the suitability of the STP for treating faecal sludge. The location of STP should be located one that can be easily serviced by desludging trucks. Co-treatment can help reduce infrastructure investment in treating faecal sludge.

Planetary model: This refers to installing transfer stations throughout the city for collecting faecal sludge. These are dedicated facilities installed strategically throughout the municipality that serves as a drop off locations for collected faecal sludge. They may include a receiving station with screens, a tank for holding the collected waste, trash storage containers, and wash down facilities. Faecal sludge from the transfer station is then transferred to the treatment facility using bigger tankers. Presence of transfer station can make safe disposal of faecal sludge economical for small desludging truck operators who would otherwise have to travel very long distances in small trucks to safely dispose of the faecal sludge.

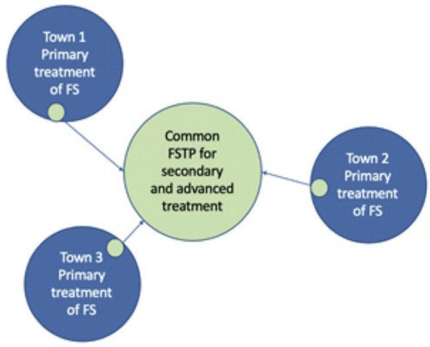


Figure 56 – Planetary Model

Co-digestion: This refers to treating faecal sludge with wet organic solid waste. This reduces the need to have separate infrastructure for the treatment of faecal sludge and wet waste. Also, this ensures optimum use of infrastructure especially when the collection of faecal sludge is intermittent.

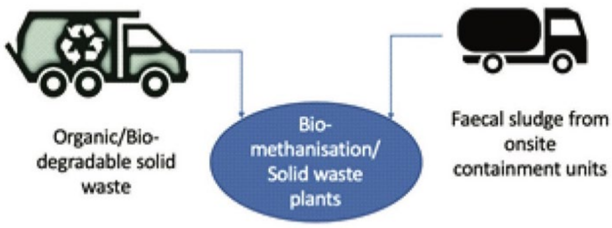


Figure 57 – Co-digestion

Co-location: This refers to locating a faecal sludge treatment facility at an existing solid waste treatment or sewage treatment facility premises. This can help in reducing the time an effort consumed in finding another piece of land exclusively for faecal sludge treatment.

Standalone FSTP: In cases where none of the above approaches is possible, the ULB must plan for a standalone FSTP.

The approach to treatment can also significantly vary based on the rural and urban divide. In India, there is significant difference between Urban and the rural areas in terms of administration, resources availability and the prioritisation of developmental issues. This can have an effect on the choice of technology options for treatment. For e.g.: a remotely located village with minimal availability of resources for maintaining the treatment systems may choose to opt for a system which is simple and easily to maintain. However a rural area located in the periphery of a urban settlement, could opt for a more mechanised system to use the land more judiciously. Similarly, based on the priority of the community towards treatment both urban areas and rural areas can choose incremental methods to adopt treatment system. For instance, they could adopt a low tech system such as trenching to solve the current issue indiscriminate disposal of faecal sludge and then plan to adopt more complex technologies based on their other objectives of treatment such as improved treatment, revenue from end products, low area foot print, etc.

The below diagrams indicate an approach for incremental treatment systems – using various parameters of treatment objectives, quantity of faecal sludge generation and the technology sophistication.

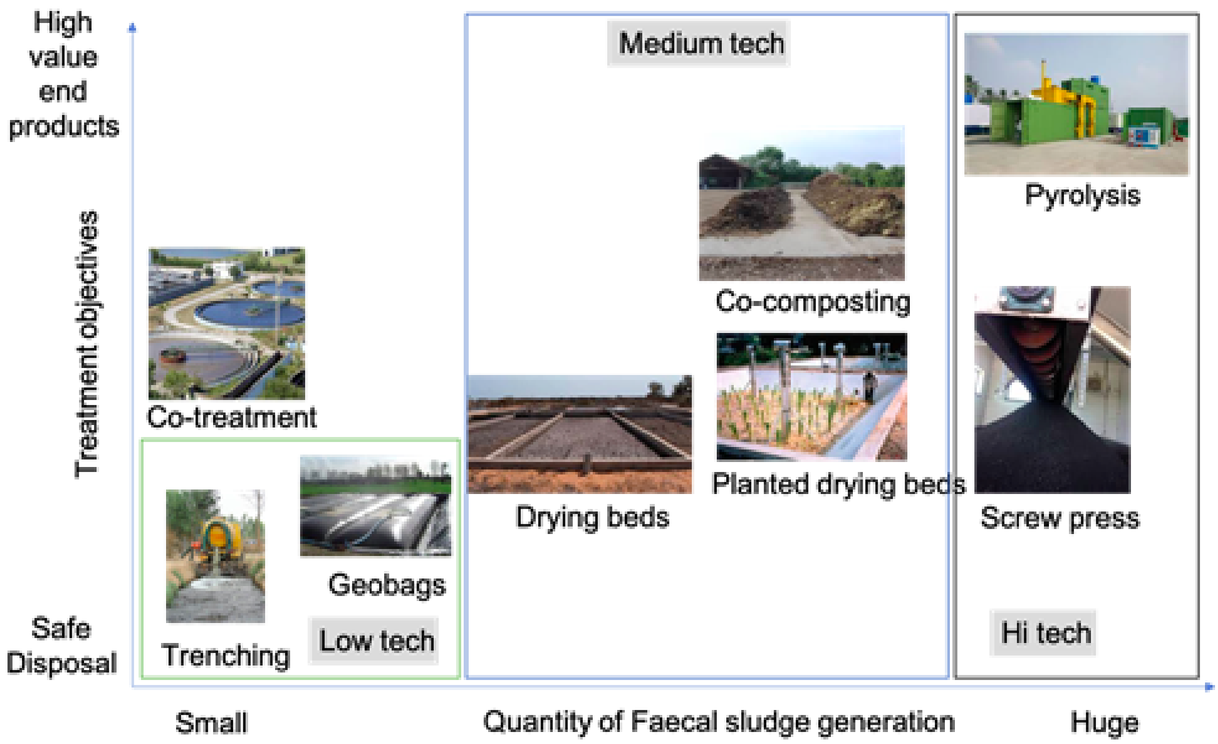


Figure 58 – Selection of treatment approach for Faecal Sludge/Septage

Treatment technology matrix

Selection of appropriate treatment technologies can depend on many factors such as a) End product requirement, b) Climatic conditions, c) Characteristics of faecal sludge and septage, d) availability of Capex and Land, e) Availability of Operation and maintenance ecosystem, among some of the major variables.

Table 10 – Matrix for selection of technology for FS/septage treatment

S. No.	Treatment Systems	Applicable Areas	Effective Treatment Volumes	Land Requirement	CAPEX (in INR)	OPEX (in INR)
1	Trenching	• Suitable for low (less than 5 cu.m.) and fluctuating volumes of faecal sludge that needs treatment • Ideal for rural areas in arid/semi-arid regions, where groundwater table is very low (more than 20m below ground) • Can also be used in peri-urban areas/fringe areas of a city, site should be away from human habitation by atleast 100m • The site should be away from surface water bodies by atleast 200m.	1-5 KLD	Huge, 0.2-0.25 sqm. per person equivalent	Nil	3,00,000
2	Geobag with constructed wetlands	• Suitable for rural and peri-urban areas where FS loads are fluctuating and volumes are less than 10 cu.m per day • Suitable for tourist places during peak seasons	1-10 KLD	Medium, 0.04 sqm. per person equivalent		18,00,000
3	Anaerobic digestion, DEWATS with co-composting	• Suitable for towns less than 1 lakh population and where demand-based desludging is planned	3-30 KLD	Medium, 0.03 sqm. per person equivalent	7,00,000 per KLD	12,00,000
4	Planted drying beds with DEWATS	• Suitable for towns less than 50,000 population and where demand-based desludging is in planning • Ideal for fluctuating FS treatment volumes	3-10 KLD	Medium, 0.04 sqm. per person equivalent	6,00,000 per KLD	10,00,000
5	Thickening tank, DEWATS and drying beds	• Suitable for towns and cities upto 5 lakhs population with demand-based desludging (or) 1 lakh for scheduled desludging	15-75 KLD	Medium, 0.03 sqm. per person equivalent	5,50,000 per KLD	24,00,000
6	Screw press, belt dryer and pyrolysis	• Suitable for cities with a population higher than 1 lakh • Suitable for cities with an industrial base	15-70 KLD	Low, 0.01 sqm. per person equivalent	4,50,000 per KLD	24,00,000

6 Citywide FSSM Planning

Figure 59 – Key steps in FSSM Planning

6.1 Assessment of existing situation

The assessment of the initial situation, which is the first step in the planning process is crucial, as it provides the baseline information for decision making. The main goals of the assessment of the initial situation are to set the scene, understand the context, get to know stakeholders and provide enough information to start elaborating the Faecal sludge management scenarios, including context specific design parameters and therefore this characterized mainly by data collection via different options. It is necessity to understand baseline information at the beginning stage of the Faecal sludge management planning process and to identify the data needs to be collected. It is important to identify the shortcomings and challenges of an existing Faecal sludge management system and able to describe an enabling environment.

6.1.1 Data to be collected

- Population and demography: number of inhabitants, number of people per household, population density and growth rate, type of housing
- Water and hygiene: drinking water coverage and infrastructure, drinking water sources, types of supply (e.g. networks, taps in houses, fountains, trucks), operators (public/private), prevalence of diseases related to faecal matter
- Physical characteristics: geomorphology, hydrologic basins, areas prone to flooding, types of soil, ground water table
- Climatic data
- Storm water management
- Local economy: main economic activities in the city, main sources of household revenue, average income

Table 11 – Relevant information of existing sanitation services

Latrines and onsite treatment	
Water availability	Information on existing water supply services (including daily consumption per household) can be used to estimate daily wastewater production
Sanitation facilities	Current levels of service (household and shared facilities) including approximate household coverage and number and location of communal or public toilets
Onsite treatment	Types of onsite sanitation system serving households with household connections
Waste collection and conveyance	
Existing sewerage infrastructure	Coverage of sewerage and proportion of household with household connections
Faecal sludge and septage collection services	Coverage and frequency of servicing
Offsite wastewater treatment and reuse	
Wastewater treatment	Location and types of wastewater treatment infrastructure (if any exists)
Discharge or end-use	Location where wastewater and faecal sludge is disposed or end-used

6.1.2 Tools and Methods of data collection

The collection of good quality data is not an easy process, especially in contexts where data is scarce, not collected or analysed properly, or hidden or manipulated for political or personal reasons. Governmental agencies usually have the reports, statistics and maps that can serve as a preliminary introduction.

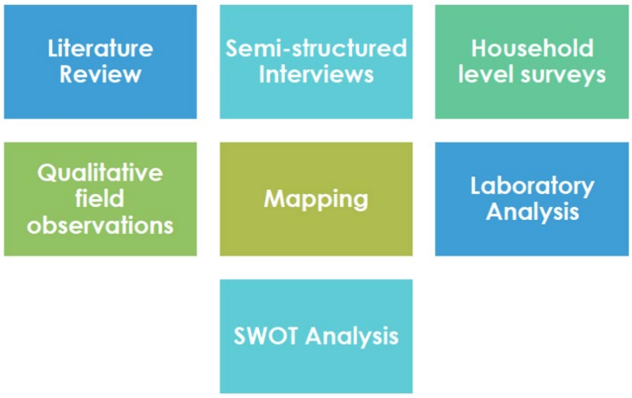


Figure 60 – Tools and method of data collection

6.2 Stakeholder analysis

Managing faecal sludge at city level in an efficient and sustainable way requires the involvement and support of all concerned key stakeholders. Stakeholders is mean that any group, organization or individual that can influence or be influenced by the project. In order to understand and engage stakeholders, stakeholder analyses should be performed. Stakeholders analysis is the process of identifying and characterizing the stakeholders, investigating the relationships between them, and planning for their participation. It is vital tool for understanding the social and institutional context of a project or a policy. Its findings can provide early and essential information about who will be affected by the project and who could influence the project, which individuals, groups or agencies need to be involved in the project and whose capacity needs to be built to enable them to participate. Identification of stakeholders is one of the important tasks when starting a new project.

Figure 61 – Key Stakeholders

Municipal Authorities	• Mayor • Municipal technical services (environment, sanitation, hygiene and public health) • Muicipal police
Regional and National Authorities	• Regional director e.g. Sanitation, Health, Hydraulics, Water Company, Public Works, Statistics, Urbansm and Habitat, Local development, Agriculture
Utilities	• Public, Semi-private (parastatal) or private (commercialised)
Traditional Authorities and Influential Leaders	• Ethnic leaders • Neighborhood leaders • Religious leaders
Small Scale FS Businesses	• Mechanical service providers, FSM business owners, FSM business owners associations or interest groups
Organizations active in Sanitation	• CBOs • Local or international NGOs • Universities, research centres • Donor agencies
Potential endusers	• Farmers, Farmers associations and institutions helping farmers • Fuel consumers
Household	• Users or Owners

Table 12 - Typical characteristics of the main stakeholders and actions to be undertaken

Stakeholder categories	Main interests	Opportunities	Involvement needs and required actions
Municipal Authorities	• Public health • Cleanliness of the city • Collection and management of sanitation fees	• Power for enforcement through regulatory framework and police • Management of treatment units • Link with other stakeholders, existing contracts and authorizations • Development of social services	• Sensitization, need for capacity building, collaboration • Institutional and regulatory frameworks often need to be developed and their application enforced • Often lack financial, human resources and land • Involve them in the financing scheme
Regional and national authorities	• Respect for laws and regulations • Capacity building • Master plans	• Collaboration between agencies, development of synergies • Support for baseline data	• Sensitization information
Utilities	• Sufficient revenues • Municipal, regional or national priorities	• Collection, transport and treatment under the same umbrella • Cross-subsidy to allow social service	• Collaboration, sensitization • Ensure that they act as 'public services' reaching low-income areas and not only upper-class neighborhoods
Traditional authorities	• Public health	• Support and land property	• Consultation, information, sensitization
Small-scale FS businesses • Mechanical service providers	• Sufficient revenues • Disposal sites close to working area • Clarification of legal status, better image	• Increase in quality of service • Lower emptying price • Collaboration with manual service providers	• Organize in association (empowerment) • Organize the market • Control the respect for rules • Contracts/ licenses should be issued by municipal authorities
Small-scale FS businesses • Manual service providers	• Sufficient revenues • Gain status, social recognition • Reduce risk at the workplace	• Improvement of working conditions	• Organize in association (empowerment) • Empowerment ('give them a voice') and capacity building • Organize a service of collection and transport or transfer of sludge

Stakeholder categories	Main interests	Opportunities	Involvement needs and required actions
Organizations active in sanitation	• Wellbeing of citizens • Clean environment • Capacity building • Visibility	• Experience in sanitation advocacy • Existing structures, human resources and competencies • Contact with households • Capacity to obtain funding	• Some organization can be of great help (facilitation, experience, and international funding) • Their relationship with the authorities should be investigated
Potential end-users	• Affordable and safe products • Yield increase	• Increase WWTP's revenue through selling of end-products	• Create end-user groups (empowerment) • Market study, and willingness and capacity to pay
Households (users and owners)	• Affordability of collection service • Clean environment	• Pressure on municipal authorities and service providers • Pay more for a better service • Better management of onsite systems	• Information, sensitization for behavior change, especially management of onsite systems • Assessment of willingness and capacity to pay • Advice for latrine construction

Table 13 – Stakeholders participation matrix

		Participation Levels			
		Information	Consultation	Collaboration	Empowerment/ delegation
Planning	Launch of the planning process	All stakeholders		Municipality, utilities	
	Detailed assessment of current situation		Key stakeholders[1]	Municipality, utilities	
	Identification of service options		Key stakeholders[1]	Municipality, utilities	
	Development of an Action Plan	All stakeholders	End-users	Municipality, utilities, FS operators, NGOs	Empower weak and non-organised groups
Implementation		Households, traditional authorities and opinion leaders	End-users	Municipality, utilities, FS operators, NGOs	Empower and delegate to municipality, utilities, FS operators, NGOs
Monitoring & Evaluation		Key stakeholders	Households, FS operators, end-users	Municipality, utilities, selected NGOs	

Table 14 – Stakeholders involvement techniques and participation levels

	Information	Consultation	Collaboration	Empowerment/ delegation
Personal meetings	■	■	■	■
Focus groups		■	■	■
Workshops	■	■	■	■
Site visits	■	■		
Media campaigns	■			
Household surveys		■		
Advocacy/ lobbying	■		■	■
Mediation		■	■	■
Logical framework		■	■	

6.3 Planning for technology option across FSSM value chain

6.3.1 Planning for technology option for containment

It is important to understand the deciding factors for selecting a suitable and appropriate containment system. For example, areas with clay, tightly packed or rocky soils, a high groundwater table or where there is frequent flooding are not appropriate for twin pit latrines. But otherwise, if sufficient water and land is available, twin pits can be a viable option. A vacuum truck should be able to access the location as the septic tank must be emptied at regular interval. A typical diagram[9] of both the systems is shown below.

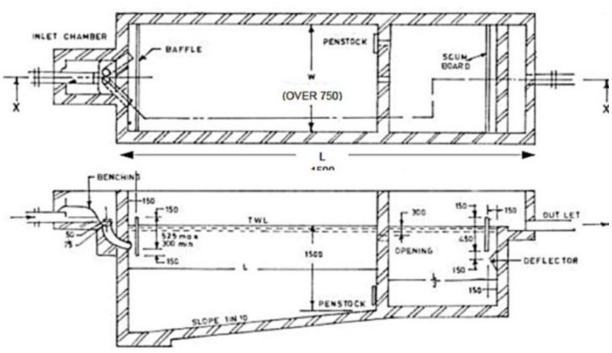


Figure 62 – Septic Tank

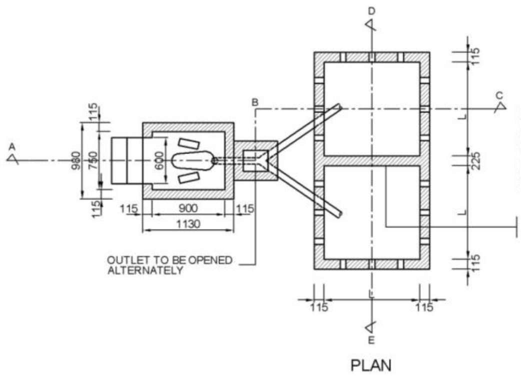


Figure 63 – Twin Pit

[9] Typical diagram of both septic tank and twin pit is taken from Manual on sewerage and sewage treatment systems, Part A: Engineering, CPHEEO, 2013

Table 15 - Comparison of a septic tank system with a twin pit

Parameters	Septic Tank	Twin Pit
Applicability	• Non-availability of sewer network • Suitable in peri-urban settlements without centralized system	• Water use 25-50 LPCD
O&M requirement	• Desludging is required once in 2-3 years • Septage must be transported for further treatment before disposal	• Desludging is required once the pit is full • Safe to desludge manually after 2-3 years
Risk and Limitation	• Cost and space requirements are high • Retention time is insufficient if it receives too much waste water • Unregulated desludging may violate the manual scavenging act, 2013	• Manual desludging of excreta and its disposal before the cleaning cycle of 2-3 years • Bottom of the pit should be atleast 2m above the groundwater table • Not designed to cater grey water
Soil characteristic	• Must be suitable for infiltration of effluent	• Highly permeable soil

Criteria for selection of containment system:

- Availability of space
- Soil and groundwater characteristics
- Type and quantity of input
- Desired output
- Availability of technologies for subsequent transport
- Financial resources
- Management considerations

6.3.2 Planning for desludging and conveyance

Desludging can be done in broadly two ways – either on demand based or by a scheduled based system.

6.3.2.1 Demand Based Desludging

Demand based desludging system refers to a model wherein the households raise a service request for desludging service by the ULB or the private operator once the septic tank is full and overflowing. The cleaning services of the ULB are presently treated as part of complaint redressal system for overflowing OSS system rather than regular cleaning and maintenance service. The ULB operates the trucks on their own or engages private players for desludging services. Currently, demand-based desludging is prevalent in most of the cities in India. Since this is a market-driven model, the prices per trip for septic tank desludging is quite high.

If the city wants to adopt/continue with demand-based desludging, it should be regulated heavily. HHs should be made aware to desludge their tanks periodically and regulations should be made and followed for the same.

6.3.2.2 Scheduled Based Desludging:

Scheduled based desludging system refers to a model wherein the ULB prescribes a scheduled regime and provides services either itself or through its empanelled operators at a fixed time interval. For e.g.; the ULB will send alert and scheduled desludging of OSS systems in 3 years. Here, the charges are built into the annual property tax levied on the HH.

In a scheduled based system, the ULB will require additional vacuum trucks compared to demand-based system, as in the demand-based system, HHs generally request for emptying their OSS systems once in 8-10 years against the recommended cleaning cycle of 2-3 years by CPHEEO. This system requires regulations and penalties to be put in place to ensure periodic cleaning by households. Awareness generation activities are required to be undertaken by ULBs to educate households about the need for regular cleaning of OSS systems.

In this, a septage conveyance plan or a schedule is drafted. For any plan to be effective, robust data on volumes and locations are required. The ULBs should make efforts to collect baseline data – the type of sanitation systems connected to toilets, effluent disposal system, size and age of collection systems, when they were last cleaned and most importantly, their access, to plan for workable desludging schedules. It is advisable to divide the city into working zones for the same. Pilot desludging schedules can be implemented to learn operational issues and devise solutions, before scaling up to the whole ULB. While formulating zones, availability of septage disposal and treatment site/ existing STPs should and their distance from the zone should be taken into consideration. It is recommended that households in demarcated septage management zone should be within 30 km. travel distance from identified disposal sites, for workability. (Advisory Note on Septage Management in Urban India, 2013)

Prior to this planning, the ULB shall first assess its role and capacity for implementation of the septage management plan. ULB should assess various aspects of septic tank emptying like how many septic tanks are required to be emptied annually as per CPHEEO norm versus how many are emptied in a year, how many vacuum emptying trucks/ capacity of trucks are required if number of septic tanks emptied as per CPHEEO norms versus how many trucks are available/working with capacities of emptier trucks, assessing the cost per emptying visit, method of maintaining the register for septic tank emptying services database etc. (Guidelines for Septage Management in Maharashtra, 2016).

Table 16 – Scheduled Vs. On-demand Desludging

Scheduled Desludging	Demand Desludging
• Services at the predefined regular schedule (generally 3-5 years) as determined by the city • City divided into zones for desludging • Works as a public service model • Service either by ULB or registered private sector • Charges can either be taken through user charges or sanitation tax (can be levied if desludging provided as a service to the citizens)	• Services upon request i.e. demand based • Works as a complaint redressal model • Service by ULB (depending on capacity) or private sector depending (may or may not be licensed) and user charges are taken from households
Pros: • Pro-active system wherein desludging is offered as a public service to the HHs • Services are offered to all HHs in the city thereby comparatively more equitable	**Pros:** • HHs decide when to avail to desludging services

Scheduled Desludging	Demand Desludging
• More cost effective due to efficiency gains and optimal business structure • Comparatively more affordable to HHs since charges to be paid every year are low • Positive implications on the health of the community and environment over a period of time	
Cons: • Participation by HHs and their willingness to desludge every 3-5 years which may need extensive IEC activities • Comparatively more infrastructure requirement	**Cons:** • Very low desludging frequency by HHs • No control over desludging charges. Can vary substantially with generally high prices per trip • Need strict monitoring so that septage is disposed at the designated site and not in any other area in and around the city • Low efficiencies of septic tanks with poor quality effluent overflow being released in rivers/ water bodies causing negative environmental impact

6.3.2.3 Desludging Operations

There are primarily two models for provision of desludging services in a city:

Model 1: ULB manages the desludging on its own

In this model, the ULB owns, operates and maintains the desludging vehicles. The ULB has to ensure adequate number of vehicles of different sizes. The ULB has to also ensure adequate number of skilled human resources to operate these vehicles for desludging. There is a dedicated number where citizens could call to avail the service. ULBs should prepare a standard operating procedure (SOP) to define standard processes of service provision.

Model 2: ULB outsources the desludging to private agencies

In this model, the ULB outsources the desludging service to private contractors. The selection of private agencies for emptying OSS should generally include the service providers' past experience, availability of mechanical emptying vehicles, trained human resources and adequate safety gears.

In this model, after receiving the desludging request from the HH, the ULB diverts the service requests to the empanelled agency. Even after outsourcing, the ULB should ensure appropriate monitoring of the service providers and compliance with the ULB's standard operating procedures.

Technology options for emptying and conveyance of septage

Currently many ULBs do not have appropriate vehicles as well as adequate numbers for desludging septic tanks. It has been seen that if ULBs have the desludging vehicles, they do not have adequate drivers or helpers to run the vehicles and provide the service. HHs thus find it easier to call private contractors to desludge their septic tanks which may not be undertaken in a safe manner.

Selection of appropriate vehicles is the first step and various selection criteria have to be considered to select the appropriate vehicle. If the city has procured certain large capacity of desludging vehicles, but does not have adequate and skilled human resources to run those vehicles or has an area of the city where the roads are narrow and cannot be accessed by the large trucks, then the desludging plan for the city is bound to fail. The criteria for selection of appropriate vehicles should include the following:

- Road widths/ condition/ terrain
- Quantity of faecal sludge and septage generated
- Financial resources available
- Availability of skilled human resources to operate and maintain the vehicles
- After sale service/ skill for repair of the vehicle
- Method of desludging – (will affect the number of vehicles)

The first and most important criterion is to assess the quantity of septage generated in the city, and from which parts of the city. Smaller sized vehicles would be more useful for a city which has narrow lanes.

Demand based desludging may require lesser number of vehicles than scheduled based desludging. This initial level assessment has to be made before procuring the vehicles. Types of vehicles generally used for desludging are:

- conventional vacuum trucks used for desludging septic tanks which can be accessed through broader roads,
- mini vacuum tankers which can be used where the septic tanks are located on narrow lanes and do not have proper access to roads, and
- Gulper which is smaller mechanized tricycle or motor cycle mounted collection tanks of 20-40 litres capacity with smaller vacuum pumps at the primary level backed by a secondary transport system and which can be used in informal and slum and slum like settlements and very narrow road lanes.

6.3.3 Planning for Technology Options of Treatment and Reuse

6.3.3.1 Estimating quantity of septage generation in the ULB

Quantity of septage generation in the city is required prior to establishing a treatment plant. Based on an 'Advisory Note on Septage Management in Urban India, MoHUA' and United States Environmental Protection Agency (USEPA) 1984, per capita septage generation can be assumed at 230 litres/year. This means, by multiplying the current year's population of the ULB with 230 litres/year, the ULB can estimate the quantity of total septage generation in the city in a year.

For more precise estimation of septage generation, the ULB could conduct a sample survey of different types of properties connected with OSS. From the survey, the ULB could then derive the total septage volume generated across the city.

6.3.3.2 Planning for Treatment and Disposal Site

The ULB has to assess the existing infrastructure available in the city before planning to establish a FSTP. If the ULB is partially covered with sewerage network and has a functional STP, then the septage can be disposed in the sewer line. Before that, the ULB needs to ensure the capacity of STP to take the additional load for treatment of septage.

If the ULB currently has no sewerage network but has plans to establish the same with functional STP in next 2-3 years (in case these have been approved as part of service level improvement plan (SLIP) under the AMRUT or any other state government supported schemes or self-financed), it is advisable to construct sludge drying beds and dispose the septage in sludge drying beds till the STP become functional. This is an interim solution to manage faecal sludge and septage safely.

If the ULB is currently not covered with sewerage network or a STP, and it has no plans to establish the same; the ULB can decide to construct a FSTP similar to Devanahalli. To establish FSTPs, let us discuss the parameters to be considered to identify a new septage treatment site.

Identification of New Faecal Sludge Treatment Site

To identify a new treatment site, the following parameters should be assessed:

Land availability**:** Availability of government land for establishing a treatment plant. Private land will cost more to acquire it for setting up a treatment plant.

Distance of treatment site: Long distance of treatment site will lead to higher fuel cost and might result in lesser trips.

Neighborhood: the treatment plant needs to be appropriately distanced from a residential area. The site's immediate environs need to be assessed.

Uninterrupted electricity: The treatment plant will require a reliable power supply for its efficient functioning, if the treatment technology has mechanical parts for its operation.

Geological parameters: Geological parameters such as depth of groundwater table at the selected location and type of soil should be considered. Also it will be an advantage if the selected site is not prone to flooding and it should not be a low-lying area.

Factors to be considered for Choosing Treatment Technology

Various treatment technologies are available and the ULB should carefully assess based on the selection criteria and then decide a suitable technology. ULBs need to know the advantages and disadvantages of the treatment technology and should assess how much mechanization is required to run the treatment plant. ULBs should also assess the geological condition of the site and requirement of capex and opex for the treatment technology. A full life cycle cost of the plant should be worked out for the technology and it should be viable for the city to comfortably operate and maintain the same.

Septage Treatment Options

Septage can be converted into compost or energy after its treatment. Various available options for septage treatment are listed below. The ULB may choose a combination of these technologies. These technologies are identified based on the national and international case studies.

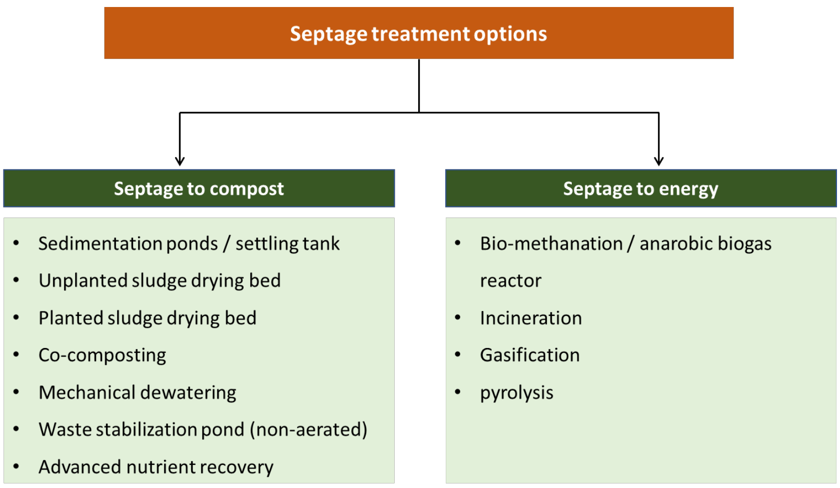


Figure 64 – Faecal Sludge/Septage Treatment Options

6.3.4 Financing of the FSSM

After understanding all the components of the FSSM value chain, it is essential to identify the possible financial sources to implement the FSSM plan in the city. Currently, SBM, Smart Cities Mission and AMRUT are the missions which have fund allocation for implementing FSSM in the city. Funds can be availed from the SBM for construction of individual toilets, public toilets, community toilets and OSS systems. Whereas fund for procuring vehicles and equipment for conveyance of septage, establishing treatment plant and disposal site, can be availed from the Smart Cities Mission and AMRUT mission.

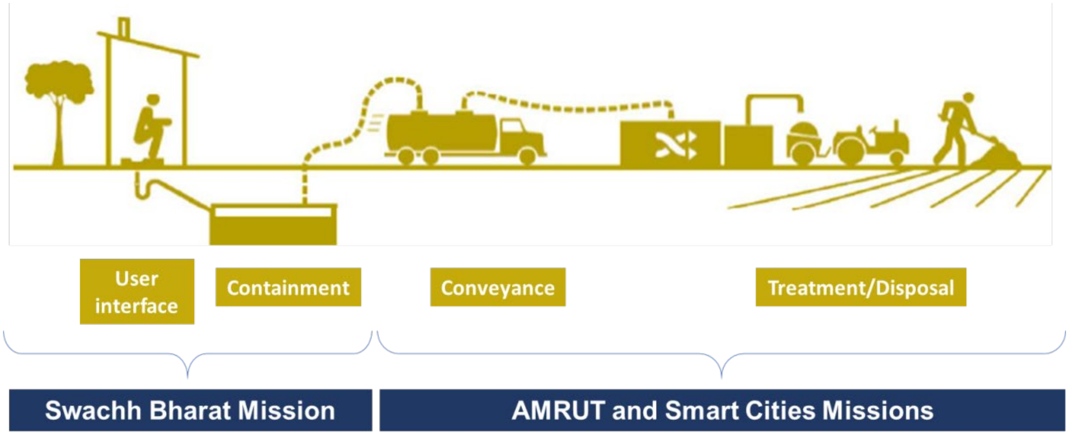


Figure 65 – Source of funding across FSSM Value Chain

6.3.4.1 Capital and Operational Expenditure

Capital expenditure

CAPEX of the project refers to all the expenditures which will happen only once for setting up or implementation of the project. Following are few examples of capital expenditures;

- Cost of land and site preparation
- Civil structures, electrical and plumbing components, electromechanical components
- Establishment cost
- Site investigation
- Transport and overhead.

Operational expenditure

OPEX can be classified into (1) direct costs and (2) indirect costs.

Direct costs refer to the expenditure which variable and depend on the degree or hours of operations. Ex. Cost of electrical energy, cost of polymers (coagulants).

Indirect cost refers to the expenditure which is fixed and does not depend on other factors such as load of FSS received etc. Ex. Lease of the land, human resource cost.

Income and revenue

Income and revenue refer to the incoming monetary streams. In case of FSTP, revenue can be generated through, (a) discharge fees, (b) purchase fees and (c) budget support.

Life cycle cost analysis

LCA refers to the process which account the CAPEX, OPEX and revenues over the life period of the project and gives a single cost. Depending upon the type of analysis used, the ultimate derived cost is known as annualized cost or net present value etc.

It is recommended to compare the LCC of project to choose suitable technologies for treatment of FSS. The non-mechanized (natural treatment) components for treatment of FSS require larger area and typically have more CAPEX as compared to mechanized components. However, the OPEX of the non-mechanized component might be lesser as compared to mechanized component. Hence LCC gives a much more holistic picture of the cost of treatment.

LCC also gives an opportunity to check the financial viability of the treatment of FSS, as the cost of treatment needs to be covered by the end beneficiaries i.e. the households and/or ULB.

Table 17 – Assessment of CAPEX and OPEX across FSSM Value Chain

	User interface	**Containment**	**Conveyance**	**Treatment/Disposal**
capex	Construction of new individual toilets, PTs and CTs	Construction of new septic tanks and refurbishments of septic tanks	Procurement of new suction emptier trucks	Land cost and construction cost of treatment plant
opex	Maintenance of PTs and CTs	-	Fuel cost for emptier trucks, salaries of drivers, maintenance of machines etc.	Operations of the treatment facility: Staff salaries, electricity bill etc.

6.3.4.2 Potential Sources of Financing for Capex and Opex

To ensure financial sustainability of FSSM services, it is important to assess capacity for financing of both capex and opex over the planned period. This can start with an assessment of financial requirements for both capex and opex, along with subsequent tariff restructuring, to make the system

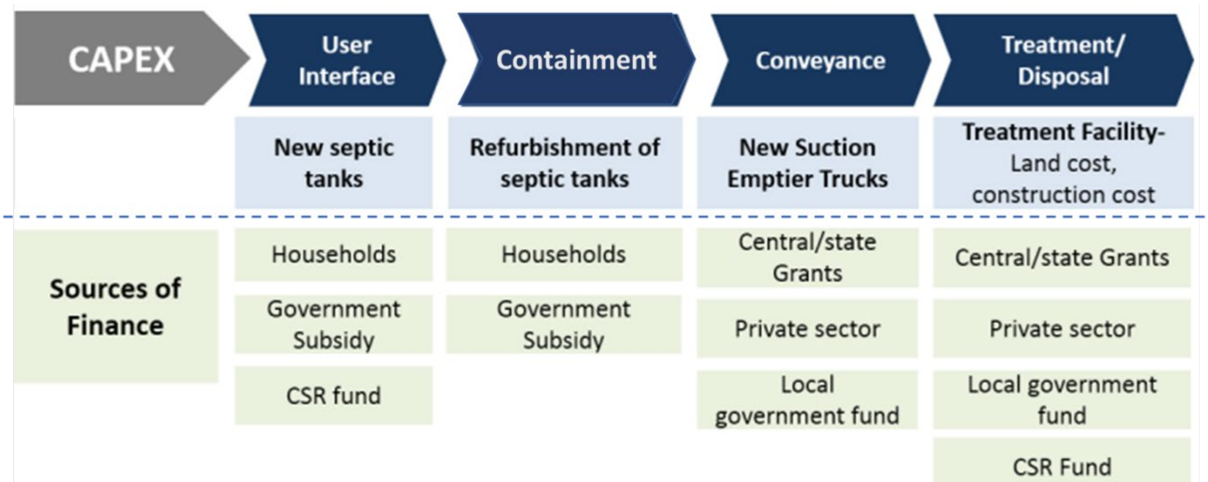


Figure 66 – Potential sources of financing for CAPEX

sustainable. The assessment also provides guidance on potential sources of finance for meeting these expenditures including funding through external grants, private sector investments, user contributions, external debt or through local government internal resources. *(Ministry of Housing and Urban Affairs, 2013)*.

The ULB needs to identify the potential financial sources available to avail fund for capex across the value chain. For construction of new septic tanks, possible sources for supporting capex include HHs, government subsidy and CSR funds. For refurbishment of septic tanks, which is a part of containment, the predominant source of capex would be government subsidy or HHs have to borne the capex. For conveyance of septage, capex can be sought from central or state grants, and under local government schemes. Private sector participation is also a potential source for capex to procure vehicles. Establishing the FSTP and the disposal site are major areas where more funds will be required if any private land needs to be procured. Possible sources from where capex can be obtained would be grants from central and state governments, funds from local government and CSR funds. Private sector participation is also a potential source of finance but willingness of the private sector is to be assessed.

The government typically will support only for the capex and not for opex; the ULBs have to explore possible sources to cover opex costs. Potential sources for opex may include housing society fees, annual sanitation tax, and desludging fees taken from the property owners on the request of desludging their OSS systems. Revenue generated by selling of product after the treatment of septage will also feed into opex revenues.

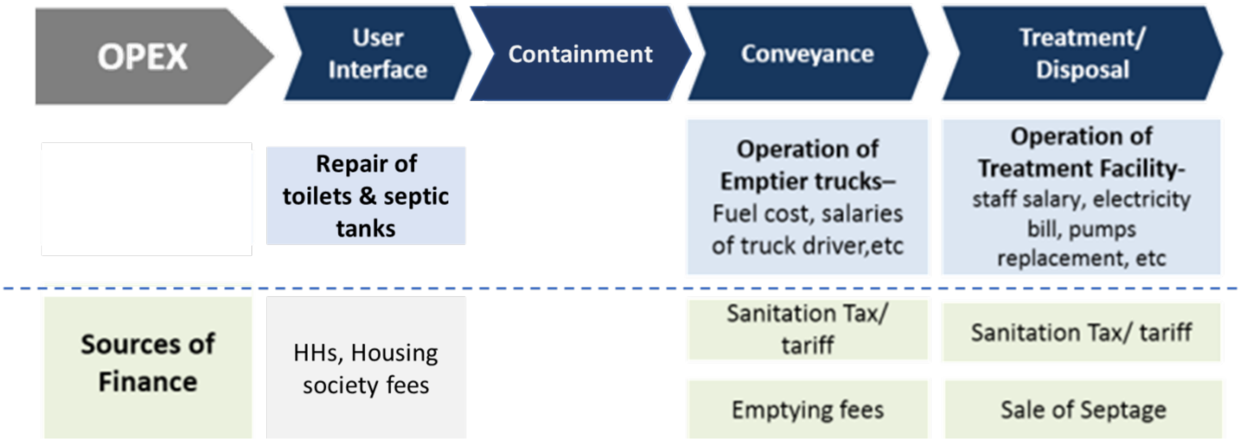


Figure 67 – Potential sources of financing for OPEX

6.3.4.3 Identification of Revenue Sources

The ULB can decide to levy taxes/user charges or both, on the HHs for FSSM services. Opex can be recovered by levying taxes and user charges from HHs. The ULBs could introduce a sanitation tax. Such a sanitation tax will be paid by the HHs to the ULB as part of annual property taxes.

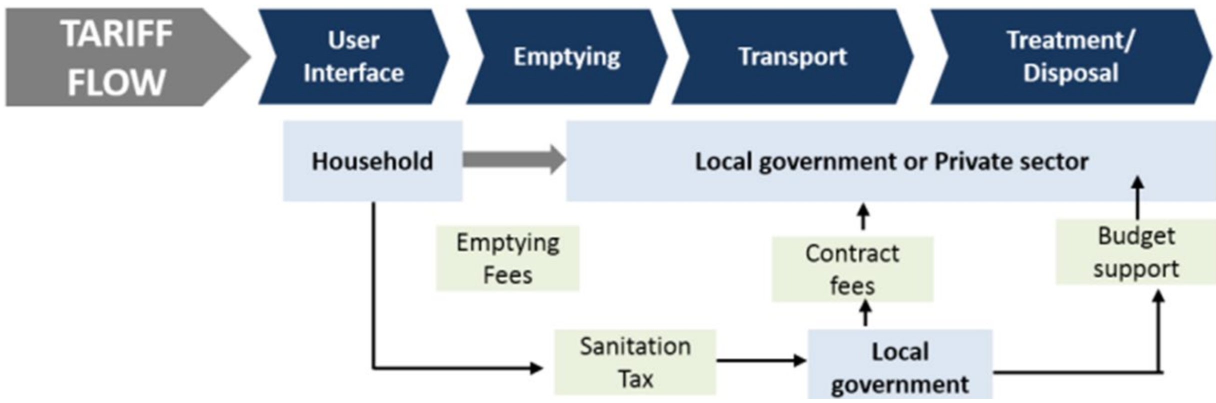


Figure 68 – Possible sources for generating revenue

6.3.5 Planning Tools

There are various tools available to guide the city managers through the process of preparation of citywide FSSM plan.

SANIPLAN tool for FSSM

SANIPLAN is a decision support tool that provides a structured approach to planning for urban sanitation. It focuses on integrated service performance with a detailed assessment of finances. It is a planning tool which can support more informed stakeholder participation. Based on local priorities, users can identify key actions for service improvement. Its dashboards also support more informed interaction with decisions makers.

SANIPLAN has three modules: 1) performance assessment, 2) planning and 3) financial planning. A key feature of SANIPLAN is to develop a feasible financing plan for both capital and operating expenditures in context of local finances. SANIPLAN can be used for various sectors – water, sanitation, solid waste, and can be customized for a specific context.

Visit https://pas.org.in to access the SANIPLAN tool

Visit https://www.youtube.com/watch?v=zWJDWwJV3xA for video on demonstration of SANIPLAN for Wai Town in Maharashtra.

SaniTab

SaniTab is an easy to use app (android based only) for conducting sanitation surveys. It can be used to generate baseline information and to create a database for properties connected with OSS systems. It can be used for planning and monitoring ODF and faecal sludge management activities in cities, or for impact assessment. It is easy to administer and allows quick analyses. Key features of SaniTab are

- Citywide digital data collection tool
- Providing enabling environment for spatial analysis
- Quick and ease in survey, minimizing human error
- Real time monitoring of survey activity

Visit https://pas.org.in to access the SANITAB tool

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