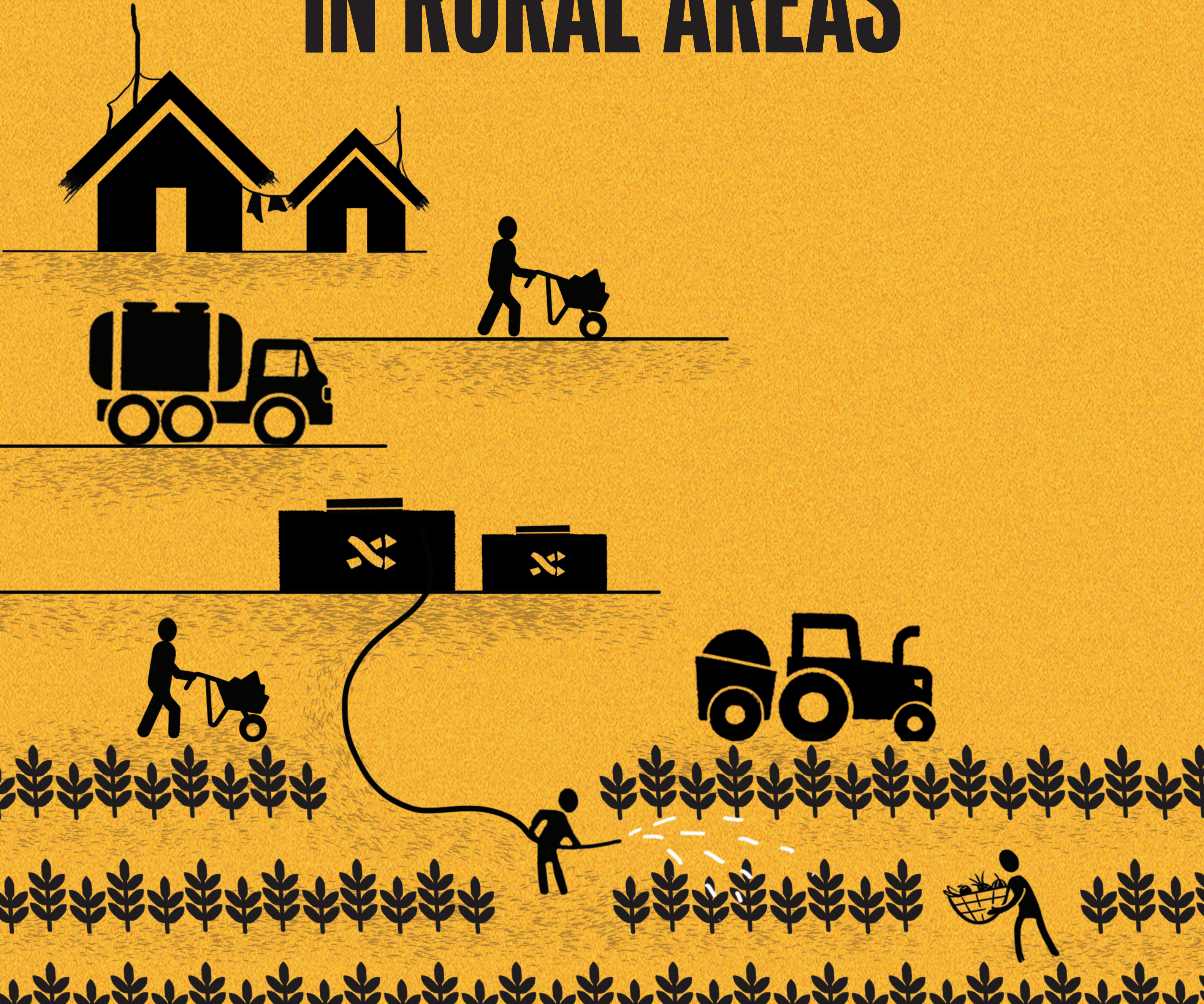
TOOLKIT

MANAGING FAECAL SLUDGE IN RURAL AREAS



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Authors: Rashmi Verma, Sushmita Sengupta and Srishti Anand

Editor: Archana Shankar

Cover design: Ajit Bajaj

Cover illustration: Ritika Bohra

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Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi 110 062
Phones: 91-11-40616000
Fax: 91-11-29955879
E-mail: cse@cseindia.org
Website: www.cseindia.org

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INTRODUCTION

KEY POINTS

- Since the launch of the Swachh Bharat Mission in 2014, toilet construction has increased by leaps and bounds, with peak of construction in FY 2017–18 in rural areas.
- Seriously addressing safe containment and management of liquid waste from the toilets is the need of the hour.
- Toilets with poorly designed pits and septic tanks generate huge amounts of untreated black water, leading to pathogens contaminating the soil and water.
- The Department of Drinking Water and Sanitation—which looks after rural sanitation—has identified in its ten-year (2019–29) strategy paper the need of safe containment, treatment of faecal sludge and wastewater by 2024.

The Swachh Bharat Mission (Grameen) (SBM-G), launched in 2014, aimed to provide every rural household with toilet facilities. The Department of Drinking Water and Sanitation, Ministry of Jal Shakti, which manages SBM, says that around 164 lakh toilets have been constructed till mid-February 2020 in 6 lakh Indian villages. The rate of increase of household toilets after the launch of Swachh Bharat Mission (SBM) has been massive. A comparison of the figures of household toilets in the first four financial years after the launch of SBM in 2014–15 shows that the construction of toilets increased in leaps and bounds, with peak construction in 2017–18 almost five times that of year one of SBM.[1] Construction of toilets on such a large scale also requires a serious thinking on safe containment and management of liquid waste from the toilets.

In rural areas where on-site containment is the only solution, an emphasis on correct toilet designs and management of liquid waste from the toilets as well as bathrooms is needed to move towards safe sanitation. Studies show that wrong containment structures lead to direct discharge of toilet waste in open drains or nearby waterbodies. For example, a 2017 WaterAid study[2] of eight states of India on the quality and sustainability of toilets showed that only 33 per cent were deemed sustainably safe (eliminating risks of contamination in the long term); 35 per cent were safe, but would need major upgrades to remain safe in the long term; and 31 per cent were unsafe, creating immediate health hazards. The major issues were with technology choice, suboptimal construction, and clear neglect of local geography. The 2019 Joint Monitoring Progress Report[3] by the United Nations International Children's Emergency Fund (UNICEF) and the World Health Organization (WHO) also flags the issue of safely managed sanitation services. The survey says that governments must define safely managed sanitation to go beyond the use of hygienic toilets and to include the safe management of excreta at each step of the sanitation trajectory—from containment and emptying to conveyance, treatment and, most importantly, its reuse.

This toolkit lists the best technologies to treat toilet waste safely and presents success stories from different parts of the world.

1.1 NEED FOR MANAGEMENT OF FAECAL SLUDGE IN INDIA

Faecal sludge is undigested sludge in liquid and semi-liquid state and highly concentrated in suspended, dissolved solids and pathogens. It is also mentioned as septage when such solid and liquid parts are pumped from a septic tank. According to Energy Alternatives India estimates, a Chennai-based private organization, about 0.12 million tonnes of faecal sludge is generated in India per day.

It is essential to look beyond toilets so that the pathogens are prevented from re-entering the environment. Hence there is an urgent need to stop overflow or seepage of waste from faulty sanitation systems. Sludge should be treated before any disposal—this should be the mandate.

According to the Department of Drinking Water and Sanitation, the majority of toilets in rural India are the twin leach-pit type, which are specially built with two honeycombed pits dug into the ground. In this system, faecal material empties into one pit while the other remains shut. Because of the honeycomb design—which uses bricks for construction—the toilet is a self-contained treatment plant in itself and does not require any additional blackwater or faecal sludge management. The liquid leaches out of the pit and the pathogens die within a few feet of the pit, while the solid material remains in the pit. Once the first pit fills up in five to six years with continual use by a family, the faecal material is diverted to the second pit and the first pit is shut. In about six months, the material in the first pit converts into pathogen-free organic manure which is safe to handle by hand and use for agriculture.

But on-site checking presents a different story. The National Annual Rural Sanitation Survey (NARSS), the 2018–19 nationwide survey funded and used by government to establish the success of the Swachh Bharat Mission, includes examination of the type of toilets being constructed and also defines what safe disposal of human excreta is. According to it, the bulk of toilets in rural India—34 per cent—are septic tanks with soak pits. Double-leach toilets account for roughly 30 per cent. The remaining toilets are single pit and closed pit.

NARSS includes in safe disposal toilets that have septic tanks with soak pits, single leach pits, double leach pits, closed drains with sewer systems and closed pits. It does not examine how often or where—waterbody or land—the excreta is disposed of. The quality of construction is another issue, even when it comes to building double-pit latrines, with honeycomb for liquid waste disposal. In both well-constructed honeycomb as well as septic tanks, the liquid is discharged either into the ground or in drains and the solid (faecal sludge) is allowed to remain in the pit or tank till it is decomposed and safe to use on land. But it is completely dependent on the quality of construction of the toilet. If the septic tank or the twin pit (honeycomb) is not built to specifications, the waste will not decompose and when it is removed it will have pathogens and will contaminate land or water.

There is inadequate information about this aspect from government sources and therefore this remains a source of concern.[4] Given this, it is inevitable toilet waste is directly discharged into open drains and waterbodies in many rural areas of the country. In many cases, it is seen that the solid (faecal sludge) is collected from on-site containment systems and disposed of without treatment into agricultural fields and fisheries, adversely affecting human health. Manual handling of untreated faecal waste creates havoc.

The Department of Drinking Water and Sanitation in the latest (2019) publication emphasized on proper management of faecal sludge along with solid and liquid waste management (SLWM) activities to leap from an open defecation free (ODF) state to an ODF Plus state and sustain sanitation gains made by SBM-G. The key approach suggested was to retrofit existing toilets that failed to serve the objective of on-site sanitation facilities. If retrofitting was not possible, it was suggested that faecal sludge be treated at treatment plants.

1.2 EXISTING POLICIES, STRATEGIES AND LEGAL FRAMEWORK TO MANAGE FAECAL SLUDGE IN INDIA

To understand how faecal sludge management will be regulated in rural areas, it is important to know what aspects of faecal sludge management existing laws, strategies and policies are highlighting. Some are listed below:

A. Environmental laws: The environment laws include the Water (Prevention and Control of Pollution) Act, 1974 (the Water Act) and the Environment (Protection) Act, 1986 (the Environment Act). Taken together, the implication of the environment laws is that:
   - Discharge of any solid, liquid or other matter into waterbodies and on land is restricted and requires specific prior approval, and
   - Depending on the type of discharge, and whether the discharge is on land or in waterbodies, permissible standards are prescribed.

B. Panchayati Raj laws: States are in charge of public health and sanitation but this legislative and functional power of the state can be delegated to institutions or local self-governments. As per the 73rd Amendment of the Constitution, states have established Panchayati Raj Institutions (PRIs), which are three tier—with gram panchayats (village level), block or taluka panchayat (intermediate level), and district or zila panchayat (top level). The 14th Finance Commission identified 'core functions' of PRIs, which include 'sanitation, solid waste management and drainage'. Studies have shown that the states have already delegated power and functions related to sanitation to the PRIs.

The provisions of the Panchayat Act show that PRIs may already have the legal mandate to provide for most activities relate to faecal sludge management (FSM). The following activities may be taken up by the PRIs for FSM:

- Survey insanitary latrines and monitor the setting up of on-site containment structures,
- Carry out mandatory 'scheduled desludging', and monitor regular and periodic desludging,
- Enforce a licensing and monitoring regimen for septage transport services,
- Take up the responsibility of setting up faecal sludge treatment systems, and
- Effectively monitor faecal sludge management systems.

According to research by the Centre for Policy Research, a Delhi-based think tank, the PRI Act in some states is stronger than in others as devolution of real powers and functions happen from the state to the PRI. The research showed an effective function of the Karnataka PRI through the Karnataka PRI Act, 1993.[5] According to it, village panchayats are—apart from the general functions of providing sanitation and drainage in the village—supposed to prevent pollution of water sources and preserve them. They have the power to make it compulsory for household owners to construct covered cess pools or pits on their own plots and also clean them. The block panchayat is supposed to acquire lands for siting manure pits away from the households, and support the gram panchayats technically on sanitation projects and help them in maintenance of solid–liquid waste management systems in the villages. The district panchayats have the responsibility of supporting the gram and block panchayats on sanitation and also consolidating all the village-level solid–liquid waste management systems. The district panchayat can develop its own policy and regulations and alongside regulate and evaluate sanitation activities at the district level. According to the CPR research, Karnataka's PRIs can prepare their own by-laws as per the 1993 Act. States can also prepare the by-laws for the PRIs, which the PRIs can adopt.

C. Laws for the prohibition and elimination of manual scavenging: The Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993 was supplemented by the Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013. Taken together, the two laws prohibit various activities that involve manual handling of human excreta (defined as manual scavenging), and they lay down conditions and safety standards for activities comprising 'hazardous cleaning'. The 2013 Act also requires conversion of insanitary latrines into sanitary latrines within a period stipulated by the local authority.

D. Policies to tackle urban sanitation: The National Urban Sanitation Policy (NUSP) of 2008 brought a paradigm shift from the 'conventional centralized sewerage network' approach of urban sanitation to a more holistic approach. A few states—Tamil Nadu and Gujarat (2014), Delhi (2015), Odisha (2016) and Maharashtra (2016)—have developed their septage (solid and liquid pumped from a septic tank) management guidelines. Apart from this, the Ministry of Urban Development (MoUD) has notified a faecal sludge and septage management (FSSM) Policy in 2017. The key features of the policy are as follows:

- Providing state-level guidelines, framework, objectives, timelines and implementation plans to address septage management,
- Formulating strategy at the central level to initiate capacity building for training on FSSM,
- Providing a sanitation benchmark framework, which shall be used by urban local bodies to develop databases and robust reporting formats, and register certified on-site sanitation systems,
- Funding for facilitation of FSSM projects and encouragement to increase public–private partnerships (PPP), and
- Achieving integrated citywide sanitation along with safe disposal.

Strategy for rural faecal sludge management: According to the ten-year strategy (2019–29) on Open Defecation Free (ODF) Plus activities, released by Department of Drinking Water and Sanitation for rural areas, faecal sludge management is the key component for the sustainability of an ODF state.

The approach for faecal sludge management will be as follows:

- Twin-pit toilets should be promoted as the preferred option for on-site faecal sludge management. Not only should newly constructed toilets have twin-pit toilets but existing toilets should be retrofiitted to twin-pit toilets in all possible areas.
- States should be flexible to take up appropriate technologies as per local conditions. These systems should not only be easy to operate and maintain but should also have low operation and maintenance (O&M) costs.
- For the treatment of the faecal sludge in treatment plants, the option for co-treatment with sewage in the nearby existing sewage treatment plant will be preferred where rural areas are near urban centres.
- Faecal sludge treatment plants will be planned for cluster of villages.

The strategy paper[6] explains different the technological options for treating faecal waste though on-site sanitation will be chosen according to the local conditions (*see Table 1: Technological options for onsite sanitation systems*).

Table 1: Technological options for on-site sanitation systems

Local condition	Technological option
In areas with a high water table and areas prone to seasonal flooding	Raising the pit above the ground and covering the exposed part with earth by making a mound for absorbing the leachate
Cold mountainous regions	Pits to be constructed below the frost line
Areas with rocky soils where fissures in rock spread pollution	Toilet linked biogas plants, EcoSan toilets and septic tanks with secondary treatment systems can be used

Source: From ODF to ODF Plus Rural Sanitation Strategy 2019–2029. Department of Drinking Water & Sanitation. Ministry of Jal Shakti, Government of India

According to the paper, retrofitting of faulty toilets is an important for the sustainability of an open defecation free state. The key approach for this is as follows:

- Toilets that are not constructed as per standards or have single pits should be upgraded to twin pit toilets;
- Where septic tanks do not have soak pits, soak pits should be constructed; and
- Toilets that may become defunct in the long run should have plans for their repair.

The strategy paper has compiled all the options for faecal sludge management in rural areas (*see Table 2: Approach to faecal sludge management in rural areas*).

Table 2: Approach to faecal sludge management in rural areas

Type of containment	Context/issue	Remedy	If remedy not feasible
Twin-pit toilet	Leaks in Y-junction	Retrofit	Co-composting with organic or solar drying with long storage is recommended for materials recovered from pit emptying
	Less than 1 m between pits	Retrofit	
	Rim of pits allow rainwater to enter pit	Retrofit	
	In areas with high water-table or those too close to groundwater source	Upgrade to in situ treatment where the solid and the liquid will be diverted to different chambers and treated separately and/or by application of bacteria	Implement FSM
Single-pit toilet	All single pits will be considered for upgradation	Upgrade to twin-pit toilet	Implement FSM
Septic tank	Require desludging at periodic intervals	De-sludge every three to five years	Implement FSM

Source: From ODF to ODF Plus Rural Sanitation Strategy 2019–2029. Department of Drinking Water & Sanitation. Ministry of Jal Shakti, Government of India

Apart from the faecal sludge, the strategy paper also talks about grey water management where the grey water may be treated at the community or village level (*see Table 3: Options for grey water management*).

Table 3: Options for grey water management

Level	Intervention
Community level	Community soak pits or leach pits
Village or large scale	1. Conveyance through pipes or existing open drains, if appropriate 2. Treatment systems including anaerobic systems, before drains discharge into waterbodies 3. Waste stabilization ponds or any other appropriate system

The Department of Drinking Water and Sanitation is the nodal department for implementation of this strategy within the ten-year period 2019–29. The institutional structures at the state and district levels will continue as with the SBM-G. Panchayati Raj Institutions (including subcommittees of the panchayat that focus on water and sanitation) will be given the primary role for implementing the strategy at the local level. States will have the flexibility to adopt the appropriate institutional structures to the local context.

CHAPTER 2
ON-SITE SANITATION TECHNOLOGIES FOR RURAL AREAS

KEY POINTS

- In rural areas, on-site sanitation systems are the only feasible solution for excreta disposal.
- Selection of on-site sanitation systems depends mainly on the soil and hydrogeological condition of the area.
- The system should be economical.
- The Department of Drinking Water and Sanitation (DDWS) has promoted twin pit with honeycomb brick structure as the most suitable technology. The brick lining should follow the specifications so that no untreated sludge or wastewater seeps into the soil or groundwater.
- Before implementing twin-pit structures in areas with shallow groundwater or those that get waterlogged easily, other options should be explored as twin pits in waterlogged areas generally fail.
- For a family of five, twin pit is the cheapest option and septic tank the most expensive. The O&M cost of the septic tank is the highest of all the available on-site sanitation in rural India.
- Technologies like twin pit, EcoSan or biogas-linked toilets can produce treated sludge for ready reuse in agriculture while septic tanks produce sludge that needs treatment.

The average amount of faecal matter produced by an adult is 500–900 gram per day.[7] The amount of urine depends on local temperature and humidity and is 0.6–1.1 litres per person per day.[8] When excreta is diluted with flushing and anal cleaning water, efficient management of excreta becomes essential.

Excreta is highly rich in nutrients (*see Box 1: Nature's subsidy*). When managed properly it can serve as an excellent repository of nutrients that are essential for soil health and can act as substitute for chemical fertilizer (*see Table 4: Recommended dose of urine for various crops in the Indian conditions*). Faecal matter should be treated before any sort of disposal so that pathogens are removed.

Treatment can be easily provided at the user level in areas that depend on on-site sanitation systems. On-site sanitation systems provide enough retention time to excreta and help turn it into bio-solids that have high nutrient value and can serve as excellent soil conditioner. As soon as excreta is deposited, it starts to decompose, eventually becoming a stable material with no unpleasant smell and containing valuable plant nutrients.

Table 4: Recommended dose of urine for various crops in the Indian conditions
(based on average values of 0.45 per cent N, 0.17 per cent P and 0.16 per cent K in urine)

Crop	Recommended dose of fertilizer (N:P:K)	Human urine litre/ha	Urine required per plant (litre)
Maize	150:75:40	50,000	0.9
Finger millet	100:50:50	33,333	0.6
Jowar	100:75:40	33,333	0.13
Pearl millet	100:65:25	33,333	0.15
Wheat	100:75:50	33,333	0.06
Paddy	100:50:50	33,333	0.29
Chilli	150:75:75	50,000	1.69
Tomato	250:250:250	38,333	3.38
Brinjal	125:100:50	41,667	1.13
Radish	75:38:38	25,000	0.11
Sugar cane	250:100:125	83,333	2.25

Source: Ecological Sanitation: Practitioner's Handbook, 2011

Box 1: Nature's subsidy

Human excreta is rich in soil nutrients. A person produces 4.56 kg of nitrogen (N), 0.55 kg phosphorus (P) and 1.28 kg potassium (K) in a year—enough to take care of 200 square metres to 400 square metres. This means India's population of one billion can produce six million tonnes of NPK, one-third the total fertilizer usage in the country.

Source: CSE

It is well established that on-site sanitation systems applied with full technical knowledge are the best solution to address excreta disposal. A range of factors affect the selection of an on-site sanitation system, including:

- Ground conditions: Bearing capacity of the soil, self-supporting properties of the pits against collapse, depth of excavation possible and infiltration rate.
- Bearing capacity of the soil: Some soils are suitable only for lightweight materials because of their poor load-carrying capacity.
- Infiltration rate: The soil type affects the rate at which liquid infiltrates from pits. Clays that expand when wet may become impermeable. Other soils such as silts and fine sands may be permeable to clean water but become blocked when transmitting effluent containing suspended and dissolved solids. Different infiltration rate is given in (*see Table 5: Recommended infiltration capacities*).
- The rate of sludge accumulation inside the pit also impacts selection of appropriate technologies (*see Table 6: Relation between rate of sludge accumulation and anal-cleaning materials*)

Table 5: Recommended infiltration capacities

Type of soil	Infiltration capacity, settled sewage (l per m^2 per day)
Coarse or medium sand	50
Fine sand, loamy sand	33
Sandy loam, loam	25
Porous silty clay and porous silty clay loam	20
Compact silty loam, compact silty clay loam and non-expansive clay	10
Expansive clay	<10

Source: WHO, 1992. A Guide to the Development of On-site Sanitation.

Table 6: Relation between rate of sludge accumulation and anal-cleaning materials

Anal-cleaning material	Sludge accumulation rate (litres per person per year)
Wastes retained in water where degradable anal-cleaning materials are used along with water	40
Wastes retained in water where non-degradable anal-cleaning materials are used along with water	60
Waste retained in dry conditions where degradable anal-cleaning materials are used	60
Wastes retained in dry conditions where non-degradable anal-cleaning materials are used	90

Source: WHO, 1992. A Guide to the Development of On-site Sanitation.

2.1 OPTIONS IN DIFFERENT ECOLOGICAL ZONES

2.1.1 Twin-pit toilets

Background:
The main components include two underground pits used alternately, a pan, water seal/trap, squatting platform, junction chamber and a superstructure. The pits are a honeycombed structure connected by a junction chamber. The pit bottom is earthen so that water percolates down to the soil.

Excreta is diverted to the second pit once the first pit is filled up. After two to three years, the excreta in the first pit degrades to biosolids, which is pathogen free and can be used as manure. The cycle continues alternately. For an average family size of five to seven people, a single pit can last for more than four years; generating about 1 cubic foot of compost per annum per person. This option is not suitable for waterlogged areas or areas that have shallow water levels.


VIKAS CHOUDHARY, CSE

Twin-pit toilet constructed in Gonda, Uttar Pradesh

Design considerations:

- The pan used should be placed on a steep slope of 28–30 degrees. The material used for the pan can be ceramic or fibre.
- The water seal/trap is of 20 mm deep. This delimits water usage to 1.5–2 litres only for flushing. It can be of ceramic or fibre.
- The size of the pits depends on the number of users. A pit is normally used for three years (assuming soil infiltration rate of 30 litre/m^2/day) (*see Table 7*: *Relationship of size of the pit and number of users).*
- The pit can be circular or square, depending on the availability of space. Adjacent rectangular and linear pits (separated by a wall) should be avoided as the space available for leaching is more in circular and square pits.
- The distance between the two pits should be equivalent to the distance between the bottom of the pits and invert level of the pipe.
- The location of the pits should ideally be placed symmetrically towards the back of the pan. In the case of scarcity of space, pits can be located under roads or lanes.

Table 7: Relationship of size of the pit and number of users

Number of daily users	Diameter of circular pit (mm)	Length of square pit (mm)
5	1,050	930
10	1,200	1,063.2
15	1,400	1,240.4

Note: 300 mm is to be added to the depth for each case for free board depth of pit from the invert level of pipe to the bottom of the pit cover

Compiled by CSE

Pit lining: To avoid collapse, the pits should be lined with bricks joined in a cement to mortar ratio of 1:6. To make the system affordable, bricks can be made up of local stones or rocks. The brick lining should be 115 mm thick (half-brick thickness) with honeycombing up to the invert level of incoming pipe. The holes created by honeycombing should be 50 mm wide. If the soil is sandy and a sand envelope is provided, the width of openings should be reduced to 12–15 mm to make the construction easy. The brick lining above the invert level of pipe up to the bottom of the pit's cover should be in solid brick work, i.e. with no openings.[9] The pit bottom should be left uncemented as twin pits will not be constructed in areas of shallow groundwater (where water is less than 8 metres below ground level). No cement and/or concrete is applied at the bottom and on the sidewalls of the pit.

After the construction of the pits, each pit is covered either with a moulded reinforced cement concrete (RCC) seal or any other local material that is used for flooring. For the complete and safe decomposition of excreta, two pits should be used alternately (the second after the first is filled).

Because of financial constraints, many areas use concrete rings instead of brick lining. Precaution should be taken so that holes of the same size produced by honeycomb are maintained in the concrete rings. Care should also be taken to ensure that the portion above the invert level of pipe up to the bottom of pit's cover is solid.

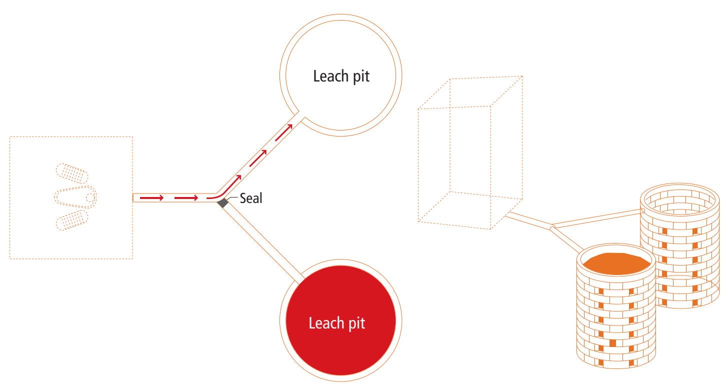
How to empty the pit?[10]
A family of five to seven members using a twin leach pit latrine (a pit of approximately 3 foot x 3 foot) consistently for six to seven years will fill one pit. The period may vary depending on the soil type or strata, size of pit and the amount of water flushed during toilet use.

The manure is ready when there is no dampness, the faecal matter turns to a black or brown soil and there is no foul smell. Before the manure is taken out, it should be ensured that there is no dampness in the soil. A hollow iron rod can be inserted till the hard strata of the pit and the soil within the rod should be checked. If the faecal matter is decomposed, it should be kept open for a day to allow flies, insects etc. to come out of the pit. If the faecal matter shows signs of dampness, ash should be sprinkled to absorb the dampness. Regular farming instruments can be used to take out the manure. Manure from the deeper part of the pit can be removed manually by entering the pit. One standard pit (approximately 3 foot x 3 foot) can be emptied in three to four hours and about 90–130 kg of manure can be taken out. The manure comes out as lumps and that needs to be loosened before packing.

Post removal of manure the following steps are to be observed:
- The pits are be cleaned.
- Honeycombing is to be checked—if it is damaged it has to be repaired.
- The pits are to be kept open for two to three days.

- Cost is low,
- Presence of flies and mosquitos controlled,
- Smell is absent,
- Removal of solids from pits easy as they are not deep,
- Pit contents can be safely used as a soil conditioner/fertilizer, and
- Maintenance is easy

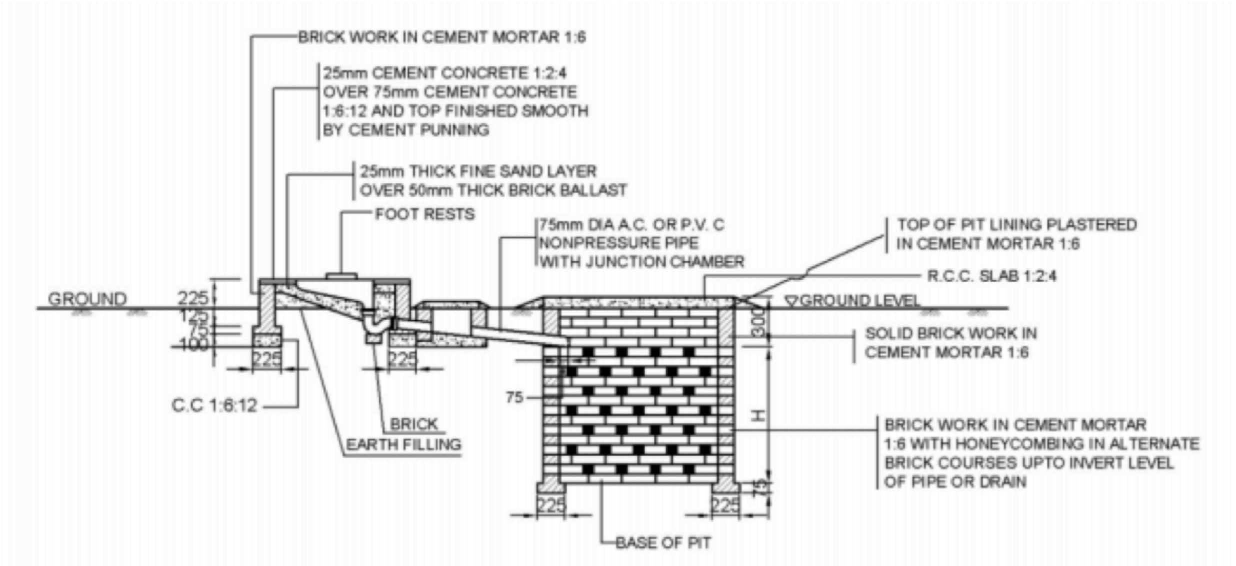
Figure 1: Design of twin-pit toilet system



- Dual pits can are used alternately.
- Both pits are connected with a junction chamber.
- Pit walls have a honeycomb structure.
- The bottom of the pit is not plastered and is earthen.
- Capacity of each pit is normally kept for three years.
- After filling up of first pit, it is blocked at the junction chamber and second pit is put in operation.
- Dug out by beneficiaries and digested sludge is used for agriculture and horticulture purposes.

Source: Tilley, E. et al. 2014. Compendium of Sanitation Systems and Technologies. 2nd revised edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland

Figure 2: Secion of a pit



Source: Suresh Kumar Rohilla, Francis Boateng Agyenim, Bhitush Luthra, Shantanu Kumar Padhi, Andrews Selom Quashie and Anil Yadav 2019, Integrated Wastewater and Faecal Sludge Management for Ghana: Draft Guidelines, Centre for Science and Environment, New Delhi

Box 2: Twin pits: A success story for Indore

Indore's progress district in achieving cleanliness is remarkable. Under the Swachh Bharat Mission (Gramin), around 56,381 toilets were constructed across the district. The communities were highly motivated to use toilets and the administration ensured that only twin-pit toilets were constructed. Mukesh Verma, District Coordinator, Swachh Bharat Mission, Indore, said, 'Demand and motivation are the main driving factors. We are focusing on the bottom-up approach. As communities realize the need for toilets, we do not need to constantly push at our end. Taking the hydro-geographical conditions into consideration, we promoted construction of twin-pit toilets, which are self-sustainable and do not require further treatment of faecal matter.'

The twin-pit toilet model is also appreciated by beneficiaries as it requires little water for flushing.
For details contact:
Mukesh Verma,
Project Officer,
Swachh Bharat Mission
DC Office,
Moti Tabela Road,
Chhatri Bagh,
Indore

Phone: 0731-2475913;
9826068773

Source: CSE

Box 3: Design calculation of twin pit in sandy soil for a household of six

Pit depth = sludge depth + infiltration depth + soil seal depth

Step 1: Daily volume of sewage: $A = P \times q$

Where P = Population and q = Sewage flow per day

If each person flushes 10 litres four times a day, the sewage flow $q = 4 \times 10 = 40$ litres per person per day;

Therefore,

$$A = 6 \times 40 = 240 \text{ litres}$$

Step 2: Volume of sludge: $V = N \times P \times S$

N = Time interval for desludging = 3 year; Population = 6; S = Sludge accumulation rate = 40

$$V = 6 \text{ X } 3 \text{ X } 40 = 720 = 0.72 \text{ m}^3$$

Step 2: Sludge depth

If each pit is 1.2 m wide and 1.2 m long, the sludge depth will be:

$$0.72/(1.2 \text{ X } 1.2) = 0.5 \text{ m}$$

Step 4: Infiltration depth

Infiltration capacity of a fine sandy soil is about 33 l/m^2 per day (Table 1)

Assuming the volume of water entering the pit each day is 240 litres, the infiltration area required will be:

$$240/33 = 7.27 \text{ m}^2$$

The perimeter length of each pit is $1.2 \times 4 = 4.8$ m,

Therefore the liquid depth will be:

$$7.27/4.8 = 1.5 \text{ m}$$

Pit depth = 0.5 + 1.5 = 2.0 m

Source: Compiled by CSE

2.1.2 EcoSan toilet

Background:

The main components for an EcoSan toilet are two above-ground tanks/vaults to be used alternately, a pan, squatting platform (with different squat/drop holes for urine and faeces), and superstructure. The tanks/vaults are watertight. The pit bottom is cemented so that the water does not percolate down to the soil. Urine is collected separately in a jerrycan to keep contents of the vault dry. A layer of absorbent organic material (ash, sawdust, shredded leaves or vegetable matter) is put in the vault after each use. This helps to deodorize the faeces, soak up excess moisture and improve the carbon to nitrogen ratio, which ensures that sufficient nitrogen is retained to make good fertilizer. The second tank is open once the first tank is filled up to two-thirds. After two to three years, the excreta in the first tank degrades to biosolids that are pathogen-free and can be used as manure. Urine can be further diluted to be used as fertilizers. The cycle continues alternately. The working life is five to six years, depending upon pit maintenance and numbers of users.

SCOPE NGO, TIRUCHIRAPALLI

EcoSan toilet at Tiruchirapalli, Tamil Nadu

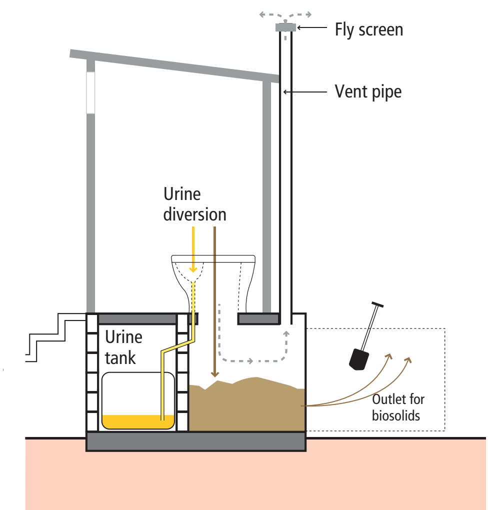
Design considerations:

- The design depends on the number of users per households.
- To design the storage volume of collection tank/vaults (for faeces), an ultimate volume of desiccated faeces and additive mixture of 0.25–0.4 litres per person per day will be considered, depending upon the local conditions and usage patterns.
- The twin chamber EcoSan toilet is most ideal for a small family as it requires minimal maintenance when compared to other on-site sanitation solutions. The dimension of EcoSan toilets with two chambers must be at least 1,200 mm x 1,500 mm.

- A minimum retention period of 10 months for pathogen inactivation of faeces and additive mixture in the faeces collection chamber must be considered in the design.
- Urine will be collected in jerrycans of 10–15-litre capacity. It can be further stored or directly transported for agricultural applications.
- The minimum floor dimension of an EcoSan toilet with a twin chamber must be at least 1.50 m in width and 1.20 m in length.
- Bricks, hollow blocks or stone/mud blocks or other locally available material can be used for the walls of EcoSan toilets to provide robust and safe construction that will last for several years.

- ➢ Absence of odours,
- ➢ Ideal for water-scarce areas and areas with a shallow water-table,
- ➢ Easy removal of solids from the pits as they are shallow,
- ➢ Pit contents can be safely used as a soil conditioner/fertilizer, and
- ➢ Works well in disaster-prone areas

Figure 3: Design of EcoSan toilets



- EcoSan is a dry toilet, with limited or no use of water.
- Excreta and urine are collected in two separate structures.
- Excreta is biologically decomposed by microorganisms (mainly bacteria and fungi).
- The ready compost is a stable, inoffensive product that can be safely handled and used as a soil conditioner.

Source: Tilley, E. et al. 2014. Compendium of Sanitation Systems and Technologies. *Second revised edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland.*

Box 4: EcoSan as success model for farmers

Shyam Mohan Tyagi, a farmer in Aslatpur village, Ghaziabad, Uttar Pradesh, has stopped using chemical fertilizer since 2006. His paddy field is nurtured on a diet of urine and decomposed human faeces. Tyagi collects urine and decomposed faeces from the special community toilet in his village.

This EcoSan—an abbreviation for ecological sanitation—community toilet is a dry toilet that separates excreta, urine and water so that waste can be used as manure with little treatment. When Delhi-based NGO Foundation for Development Research and Action (FODRA), which set up the toilet in 2005, proposed making use of the collected waste, there were no takers except Tyagi, a 30-year-old History post-graduate. Many farmers use human waste as manure but they baulked at the idea of spraying urine on food crops.

Tyagi was eager to test the pilot project on his one bigha (0.08 hectare) field. His father Moolchand Tyagi did not approve of using decomposed faeces in the field, but he went ahead and the results were encouraging. He did not have to compromise on yield while saving on fertilizers. Earlier, Tyagi used to spend Rs 1,500 per year on applying diammonium phosphate (DAP) on seedlings and Rs 1,000 on urea on grown crops and vegetables.

The toilet was ready but who would maintain it? Few showed interest in the task. Once again Tyagi volunteered.

The villagers, who did not have toilets in their homes, do not go out to defecate but use the community toilets. Within two years of motivation and awareness programmes post 2006, about 100 villagers use the community toilets regularly and a demand for household-level EcoSan toilets arose.

About the system:
EcoSan toilets do not allow water, urine and excreta to mix. The toilet pan has one hole for faeces and another for urine. The area for washing is separate, from where water goes to fields. Faeces collects in a chamber under the toilet seat. Once the chamber is full, the toilet is sealed for four months for the excreta to decompose. The gases produced during decomposition escape through a pipe in the chamber. A community toilet room has two toilet seats, which are used alternately.

After defecating, the user throws a handful of ash down the hole. This saves flushing 10–12 litres of water. Also, ash absorbs the moisture in excreta and increases its alkalinity, thereby controlling the growth of pathogens and preventing foul odours.

Urine is collected in 500-litre plastic tanks. Before it can be applied in agricultural fields, it is kept in an airtight container to prevent ammonia loss-for two months to eliminate infections.

Decomposed faeces is used as a soil conditioner. Stored urine is diluted with water and sprayed in fields.

Cost of the toilet in 2015: Rs 18,000

For details contact:
Foundation of Development Research and Action (FODRA)
130, Neelgiri Apartments
Sector-9, Rohini,
Delhi-110085

Telephone:+91 98 111 72819

E-mail: fodra.delhi@yahoo.co.in

Source: Srinivasan, R.K. 2015. Collector's item. https://www.downtoearth.org.in/coverage/collectors-item-5292

2.1.3 Septic tank

Background:
Septic tanks are also very common rural areas. According to the Ministry of Drinking Water and Sanitation's (now Department of Drinking Water and Sanitation under Ministry of Jal Shakti), the most common technology in rural areas is septic tanks with soak pits.[11] A well-designed water-tight septic tank helps in decomposing black water. Heavy solids in the black water settle to the bottom as sludge while lighter solids float on the surface of the liquid. This forms a layer called scum. The middle layer contains the least solid, which moves forward to the last chamber and is expelled out of the tanks.

Inside the tank both sedimentation and digestion take place. The retention of wastewater entering the tank is generally 24 hours—according to the Department of Drinking Water and Sanitation (DDWS) manual, it is one to two days. Anaerobic digestion of both sludge and the liquid in the middle layer takes place. The result is reduced volume of sludge, reduction of biodegradable organic matter and release of carbon dioxide, methane and hydrogen sulphide. The gases are released through a vent pipe attached to the tank. The effluent should pass through a soakaway pit as there are still dissolved and suspended organic solids and pathogens.

The main components of septic tank-based toilets include an underground tank (with a partition wall with a minimum of two chambers), a pan, water seal/trap, squatting platform, and superstructure. The tank is a water-tight brick wall connected from the toilet by the inlet pipe. The tank bottom is a cemented structure designed to achieve a hydraulic inactive state that helps in settlement of heavy solid particles. The settled sludge on the bottom of the tank must be removed periodically. The septic tank provides partial treatment of excreta after a period, usually one to three days. The efficiency of the system is 30–50 per cent of biochemical oxygen demand (BOD).

Design considerations:
- Sewage retention time of 24 hours is sufficient to allow separation of solids and stabilization of liquid.
- The depth of liquid from the tank floor to the outlet pipe invert should be not less than 1.2 m—a depth of at least 1.5 m is preferable. In addition, a clear space of at least 300 mm should be left between the water level and the under-surface of the cover slab.
- The width of the tank should be at least 600 mm as this is the minimum space in which a person can work while building or cleaning the tank.
- For efficient functioning, the tank can be divided into two compartments by baffle walls. Most settlement and digestion occurs in the first compartment, with some suspended material carried forward to the second.
- For a tank of width W, the length of the first compartment should be 2W and the length of the second compartment should be W. In general, the depth should be not greater than the total length.
- The tank floor is usually made of unreinforced concrete thick enough to withstand uplift pressure when the tank is empty. If the ground conditions are poor or the tank is large, the floor may have to be reinforced. The walls are commonly built of bricks, blocks or stone and should be rendered on the inside with cement mortar to make them watertight.
- The tank cover or roof, which usually comprises one or more concrete slabs, must be strong enough to withstand any load that will be imposed. Removable cover slabs should be provided over the inlet and outlet.
- The desludging frequency depends upon the volume of tank and the ambient temperature.

This two-chambered conventional septic tank can be improved through introduction of filter or by converting the conventional septic tank into anaerobic baffled reactor with filter. The two- chambered septic tank with filter incorporates two chambers with a single filtration chamber, resulting in improved treatment. 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. Commonly used filter materials includes gravel, crushed rocks, cinder and specially manufactured plastic pieces. The typical size of filter material is 12–55 mm in diameter. Ideally, the material will provide 90–300 m^2 of surface area per cubic metre (m^3) of reactor volume. Providing a large surface area for the bacterial mass to work on increases contact between the organic matter and active biomass, effectively degrading the organic matter. Suspended solids and BOD removal can be as high as 85–90 per cent, but is typically 50–80 per cent.

An anaerobic baffled reactor with filter is an improved septic tank with a series of baffles under which wastewater is forced to flow. It incorporates one or more filtration chambers, where particles are trapped and organic matter is degraded by the biomass that is attached to the filter media. BOD may be reduced by up to 90 per cent, which is far higher a percentage than in a conventional septic tank.[12]

- Absence of odours,
- Long life of infrastructure, and
- Readily accepted by the community

Box 5: Design calculation of septic tank for a household having five occupants

Step 1: Daily volume of sewage: A = P × q
Where P = Population and q = Sewage flow per day

If each person flushes 10 litres four times a day, the sewage flow q = 4 × 10 = 40 litres per person per day;
Therefore, A = 5 × 40 = 200 litres

Step 2: Volume for sludge: B = P × N × S
Where,
P = Population
N = Time interval for desludging
S = Sludge accumulation rate

Assume N is 3 years
S = 40 litres per person per year

Therefore, B = 5 × 3 × 40 = 600 litres

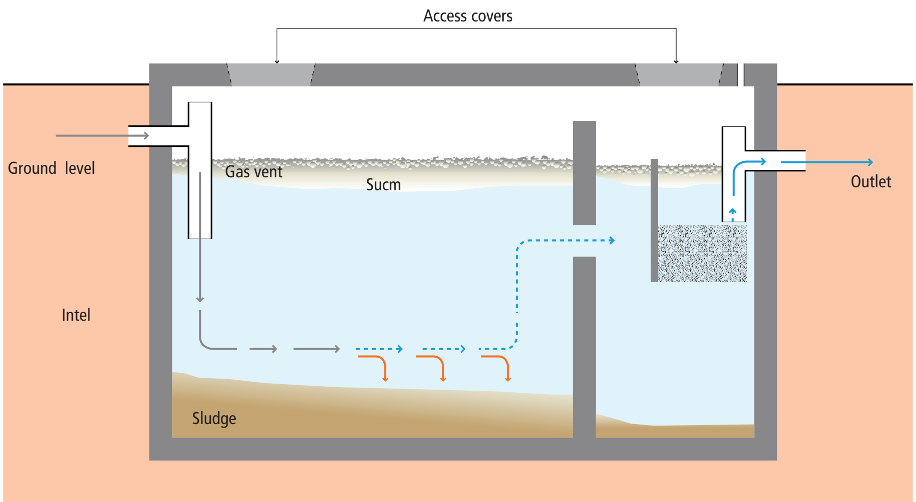
Step 3: Total volume = C = A + B
C = 200 + 600 = 800 litres = 0.8 m^3

Step 4: Dimension of septic tank
Assume liquid depth = 1.5 m
Assume tank width is W m

Assume two compartments
Length of first compartment = 2W
Length of second compartment = W
Volume of tank: 1.5 X (2W+W) X W
W = 0.47 m
As this is less than the recommended minimum width of 0.6 m, assume W = 0.6 m.
Length of first compartment (2W) = 1.2 m
Length of second compartment (W) = 0.6 m
Depth of tank from floor to soffit of cover slab = 1.5 m (liquid depth) + 0.3 m (freeboard) = 1.8 m
The tank volume (excluding freeboard) is: (1.2 + 0.6) × 0.6 × 1.5 = 1.62 m^3
which is larger than the required volume calculated in stage 3. This is not a disadvantage—in practice, either the minimum retention time will be greater than 24 hours or the tank will provide longer service than three years before it requires desludging.

Source: Compiled by CSE

Figure 4: Design of septic tank



- Septic tank is a watertight chamber made of concrete, fibre glass, PVC or plastic.
- Settling and anaerobic processes reduce solids and organics. Include two chambers with a single filtration chamber resulting in improved treatment.
- 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.

Source: Rohilla, S. et al. 2019, Integrated Wastewater and Faecal Sludge Management for Ghana: Draft Guidelines, *Centre for Science and Environment, New Delhi.*

Box 6: Shankar Balram toilet model—working on the system of digestion

The Shankar Balram toilet has a water closet with a digestion system, which is a modified septic tank. The system consists of two hume pipes of different diameters and length. The larger hume pipe is 250 cm long while the smaller hume pipe is 125 cm long. The size depends on number of users (*see Table 8: Relationship between number of users and diameter of the hume pipes*). The diameters of the hume pipes depend on the number of users. The bottom of the pipes are sealed with plain concrete cement (PCC). Effluent flows from the larger hume pipe to the smaller one through an interconnecting pipe. The interconnecting pipe is located so that undigested excreta cannot flow from the larger pipe to the smaller one without being decomposed in the larger pipe by bacterial action. The solid part of the excreta settles down at the bottom of the water, and biodegradation takes place in this layer. The effluent that passes to the smaller hume pipe is of low turbidity and without odour. The larger diameter of the first hume pipe increases the retention time of digestion. The gases released in the reaction escape through the vent pipe connected to the system. In absence of hume pipes, concrete structures can be made, but this makes the system expensive.

Table 8: Relationship between number of users and diameter of the hume pipes

Number of users per day	Diameter of the larger pipe (m)	Diameter of the smaller pipe (m)
20	0.06	0.45
35	0.76	0.45
50	0.91	0.45
75	1.06	0.60
100	1.21	1.06

Source: Compiled by CSE

Source: Ministry of Drinking Water and Sanitation, Government of India, 2016. Handbook on Technological Options for On-site Sanitation in Rural Areas.

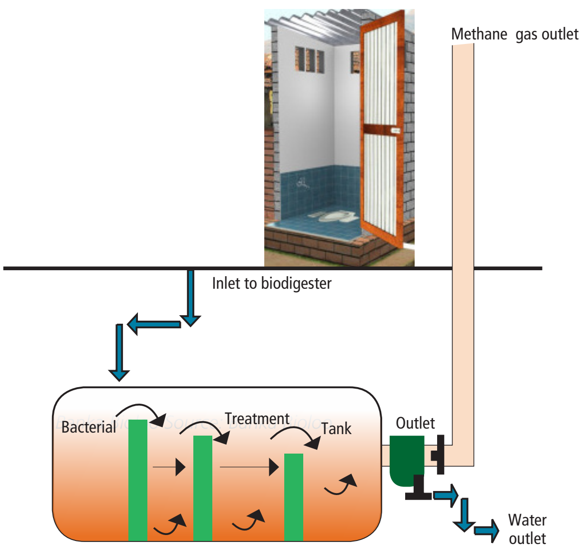
2.1.4 Biodigester toilet

Background:
The main components of a biodigester include an underground tank, which is multi-chambered (and holds the bacterial culture), a pan, water seal/trap, squatting platform and superstructure. The tank is a prefabricated and watertight structure connected from the toilet by the inlet pipe. The tank is designed to achieve a hydraulic inactive state that helps settle solid particles. The settled material undergoes an anaerobic digestion process. It provides partially treatment of excreta and the partially treated liquid passes out of the tank and is disposed of, often to the ground through attached soak pits.

Design considerations:
- The Defence Research and Development Organisation (DRDO) developed the biodigester technology as an environmental friendly, maintenance-free and efficient way of dealing with excreta.
- The prefabricated biotank is a specially designed multi-chambered tank with an immobilized matrix for retaining higher microbial mass. They are made of fibre reinforced plastic (FRP) or mild steel.
- The dimension of the biotank depends on family size.
- The biotank has two components—anaerobic microbial consortium and specially designed fermentation tank.
- The microbial consortium is composed of four clusters of bacteria belonging to hydrolytic, acetogenic and methenogenic groups, with high efficiency of biodegradation. The microbial consortium can survive cold or hot temperatures, ranging from 0°C to 55°C.
- The fermentation tank is made of metal/fibre-reinforced plastic (FRP). Because of the matrix it the tank it can immobilize bacteria in large numbers.
- The treated water overflow from the biotank is connected to the soak pits.

- ➢ Compact size, easy to install,
- ➢ Absence of odours,
- ➢ Long life of infrastructure,
- ➢ Readily accepted by the community,
- ➢ Tolerant to temperature fluctuations, and
- ➢ Low maintenance cost, negligible sludge generation.

Figure 5: Design of DRDO biodigester toilet



- The biodigester toilet (bio-toilet) is developed by Defence Research and Development Organization (DRDO), a premier Research and Development Organization of India, for the treatment of toilet wastewater.
- Normally for a household, these bio-toilets are filled up to one-third of its volume by inoculums to activate digestion process.
- Usually, the effluent is connected to a soakage pit

Source: Banka Bioloo

Box 7: Biodigester toilets developed by Hyderabad-based Banka Bioloo

The biodigester technology, developed by Banka Bioloo in collaboration with the Defence Research Development Organization (DRDO), decomposes 99 per cent of human waste effectively in a short period of time and inactivates the pathogens responsible for water-borne diseases.

One such system operates in the Banka Bioloo workshop in an industrial area in the city of Alwar in Rajasthan. The toilet is used daily by 10 persons for nine- to 10-hour shifts. The toilet is odourless and the effluent water is connected to a soak pit. Banka Bioloo claims that there is a removal of more than 90 per cent BOD in this water. The methane gas released at the outlet is vented away.

For details contact:
Namita Banka
9246880060
bankabio@gmail.com

Source: Compiled by CSE

2.1.5 Biogas-linked toilet

Background:
In biogas-linked toilets, anaerobic decomposition of wastewater takes place. This happens with the help of microorganisms that can grow in anaerobic conditions.

The main components of biogas-linked toilets are a specifically designed underground tank, a pan, water seal/trap, squatting platform and superstructure. The tank, which is watertight, is connected from the toilet through the inlet pipe can also be prefabricated. The tank is designed to undergo anaerobic digestion. It provides complete treatment of excreta, and the small quantity of treated liquid passes out of the tank and is disposed of, often to the ground through the attached soak pits. The biogas which is collected in the tank is a combination of 50–70 per cent methane, 30–40 per cent carbon dioxide and other gases. Methane can be used as fuel at household level. A standard cooking burner for family consumes half cum of biogas per hour. The gas can also be used to lit mantle lamps. A mantle lamp consumes 2–3 cubic feet of biogas per hour.

Design considerations:
- The anaerobic biogas digester is designed for integrated treatment of human excreta, animal manure and kitchen and garden waste at the rural household.
- Currently, two designs are in use—the floating drum and fixed dome biogas tank.
- The floating drum comprises a deep, underground well surrounded by a partition wall that is capped by a metal drum, which floats up and down on a track or guide pipe, depending on the volume of gas and organic materials in the well.
- Fixed dome models have gained popularity in rural communities because of the low cost to install them. The distinguishing feature of this biodigester is that it is fully integrated brick structure that has a well in the ground and a brick dome that extends out of the ground.
- The water seal is essential to prevent gas leakage.
- In the case of prefabrication, biogas tanks are made from ferro-cement or fibreglass reinforced plastic (FRP).
- The most influential factors for biogas production include temperature (mostly ranges from 15–35°C), quality and biodegradability of the organic matter and its C:N ratio, and retention time (usually 50 days). The generated biogas is stored under the hydraulic pressure of liquid displacement.
- If multiple wastewater producers (households, dairy producers etc.) are attached to the treatment facility, the cost of biogas-linked toilet per capita decreases.

Box 8: Toilet-linked biogas plants tackle faecal sludge problem in Gujarat's villages

While poor faecal sludge management in India remains a concern, a few hundred households in Valsad district in south Gujarat have shown the way by linking their toilets to biogas plants. In a 2013 project by FINISH (Financial Inclusion Improves Sanitation and Health) Society and Vasudhara Milk Cooperative, 747 households from the five clusters of Chikhali, Gandevi, Navsari, Jalalpore and Maroli in Valsad overcame resistance and superstitions associated with using human excreta.

While the initial plan was to link existing toilets with biogas units, owing to religious concerns and psychological taboos associated with human excreta the team faced resistance as people did not easily agree to mix human waste with cow dung to produce biogas. In the few homes that agreed to link the plant with toilets, logistical problems like the toilet and biogas dome not being in close proximity to one another cropped up.

An alternative strategy was then developed to approach homes with no toilets, and construct completely new biogas units and toilets. Awareness was spread through women-led mobilization teams from Vasudhara Dairy. This not only prevented open defecation and took care of treatment of faecal sludge and septage but also gave families easy access to clean and cheap fuel for their cooking needs as many of these houses earlier used dung cake or firewood for burning and cooking. Biogas is a substitute for liquefied petroleum gas (LPG) as cheap fuel for cooking and lighting and allows the use of slurry for crop production.

About the system:
A toilet-linked biogas (TLBG) system eliminates the task of frequently emptying faecal sludge from septic tanks or twin pits and dumping it in drains or landfill sites. Under it, a toilet is connected to a biogas digester using a PVC pipe. Faecal slurry flows into the digester with gravity, following which cattle dung, water and kitchen waste are regularly added to it to produce biogas, which is then used by families as cooking fuel or for other purposes like heating water.

After the gas is produced, some solid matter is left behind in the dome, which takes 20–25 years to fill, after which the decomposed waste matter can be scooped out and used as manure in the fields. The capacity of these plants is 2 cubic metres (m^3) per tonne for a family of five to seven people or less, and total gas production per day per plant is 1.5 m^3. A biogas plant with a production capacity of 2 m^3 per day will produce total 60 m^3 biogas in a month. That is equivalent to 26 kg of LPG, 37 litres of kerosene, 88 kg of charcoal, or 210 kg of firewood. A TLBG unit includes a toilet and a biogas digester, and costs Rs 32,000. The funding is arranged through various departments—Gujarat Energy Development, Gujarat Agriculture and DRDA. Also, interest-free loans are available for TLBG construction.

For details contact:
Saurabh Agnihotri
National Head—Projects and Governing Board member at FINISH
HN-353/4, Sector 4, Vikas Nagar, Lucknow 226022, Uttar Pradesh

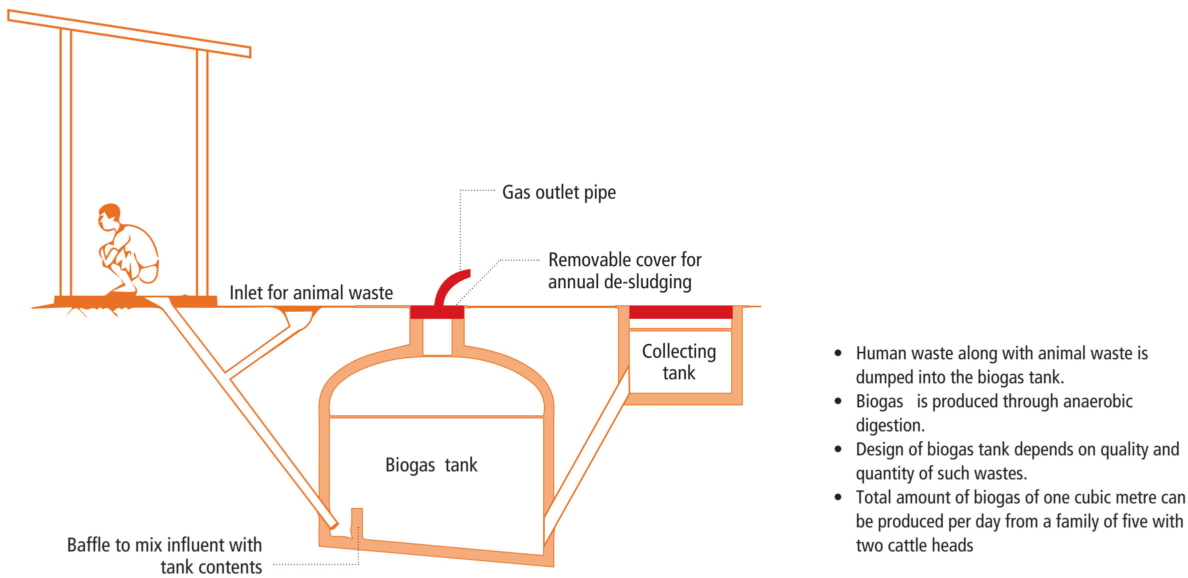
Source: Kapil, S. 2019. Toilet-linked biogas plants tackle faecal sludge problem in Gujarat's villages. https://www.downtoearth.org.in/news/waste/toilet-linked-biogas-plants-tackle-faecal-sludge-problem-in-gujarat-s-villages-64713


CSE

Toilet-linked biogas plant in Valsad district, Gujarat

- Highly efficient,
- Absence of odours,
- Long life of infrastructure, and
- Low volume of sludge generation. Does not require physical labour to remove sludge. Effluent is odourless, and cleaner, more effective and easier to use than other on-site sanitation technologies.

Figure 6: Design of toilet-linked biogas plant



Source: Franceys, R., Pickford, J. and Reed, R.A. 1992. Guide to the Development of On-site Sanitation, WHO, Geneva

Selection of technology:

The selection and design of most appropriate sanitation technology depends directly on the ground/site conditions, which regulate the bearing capacity of the soil, self-supporting properties of the pits against collapse, depth of excavation possible, infiltration rate and groundwater pollution risk. Based on the cost evaluation and comparative evaluation, the most appropriate technology best suited to the local conditions can be selected from the wide array of onsite sanitation solutions (*see Table 9: Comparison of cost (in Rs) between different on-site sanitation technologies and Table 10: Comparative evaluation of different on-site sanitation technologies*). *Table 11* gives the decision matrix for choosing a particular type of on-site sanitation system.

Table 9: Comparison of cost (in Rs) between different on-site sanitation technologies

Description	On-site sanitation technologies				
	Twin-pit toilet	EcoSan	Septic tank	Biogas linked toilet	Bio-digester toilet
Superstructure construction cost	6,000	6,000	6,000	6,000	6,000
Tank/pit/vault construction cost	6,000	10,000	12,000	20,000	15,000
Operation cost (for desludging)	Nil to 600	Nil to 500	1,200	Nil to 500	Nil to 500
Maintenance cost	200	100	200	200	250
Monetary value of urine and faeces	Medium	High	Low	Medium	Low

Source: Compiled by CSE

Table 10: Comparative evaluation of different on-site sanitation technologies

	Twin-pit toilet	**EcoSan toilet**	**Biogas plant-linked toilet**	**Septic tank**
Land requirement	Medium	High	High	Low
Water requirement	5–8 litres per user	1–2 litres per user (only for self-cleaning)	5–8 litres per user	10–12 litres
Piped-water connection	Not required	Not required	Not required	Required
Degree of skilled labour	Medium	High	High	High
Groundwater table and terrain	Suitable for generally all the areas except areas with high water-table (including coastal areas) or rocky soil or water logged areas	Suitable for any soil	Suitable for any soil	Suitable for areas with normal or high water table and rocky areas, but not for waterlogged areas
Soil strength	Can be constructed in loose soil areas if the pits are made up of perforated concrete rings	High soil strength required	High soil strength required	High soil strength required
Operation and maintenance	Low	Low	Low	High
Construction cost	Medium	High	High	High
Disposal of waste	Safe reuse of human waste in agriculture	Reuse of human waste and urine as manure	Waste converted to biogas, which is used as cooking fuel in households	Needs further treatment before reuse
Sociocultural acceptability	Acceptable	Acceptable especially in area where water is scarce	Acceptable when properly demonstrated	Acceptable
Self-building potential	High	Low	Low	Low
Suitability	Areas with water scarcity	Areas with water scarcity or prone to waterlogging	Any part	Small towns, with no centralized sewer systems and limited land available

Source: Compiled by CSE

Table 11: Decision matrix for selection of appropriate on-site sanitation technologies

	Issue	**Appropriate on-site sanitation technologies**
Type of soil stability	Loose, sides of wall collapse	Septic tank, biodigester toilet, EcoSan
	Hard to dig	EcoSan
Permeability	Clay soil	Septic tank, biodigester toilet, EcoSan
	Coarse sand	Twin pit, septic tank, biodigester toilet, EcoSan
	Hard laterite	EcoSan
Groundwater level in monsoon	Groundwater level rise more than 1 m	Septic tank, biodigester toilet, EcoSan
	Groundwater rises to or above the ground level and sludge come out the toilets	EcoSan
Distance to water sources	Distance between toilet and water resource (less than 5 m)	Septic tank, EcoSan
	Distance between toilet and water resource (more than 15 m)	Biodigester toilet, EcoSan

Source: Compiled by CSE

The ecological zones can also influence the type of toilet (both super- and substructure) that will be constructed (*see Table 12: Design considerations of key elements of toilet units for different ecological zones*).

Table 12: Design considerations of key elements of toilet units for different ecological zones

Parameter		Climatic zone					
		West coastal tropical	**East coastal tropical**	**Peninsular plains**	**Gangetic Plain**	**Desert areas**	**Eastern hill areas**
Location	Site	Good rainwater drainage essential	Good rainwater drainage essential	Good rainwater drainage essential	Good rainwater drainage essential in view of the flat terrain and possibility of water stagnation	Nothing specially required	Good rainwater drainage essential
	Layout	Toilet to be on the east–west to northeast–southwest axis to reduce heat and improve wind movement	Toilet to be on the east–west axis to reduce heat gain	Toilet to be on the east–west axis to reduce heat gains in summer	Toilet to be on the east–west axis to reduce heat gains in summer and receive heat gains in winter	Toilet to be on the east–west axis to reduce heat gains in summer and receive heat gains in winter	Toilet to be on the east–west axis to reduce heat gains in summer and receive heat gains in winter
Super-structure	Roof	Light weight, should be insulative; protection against heavy rainfall necessary.	Light-weight design for moderate rains	Medium to heavy weight, insulative, design for moderate rains, ventilation may be useful	Roofs should be designed for moderate rains. May be whitewashed for additional comfort by reducing heat gains	Roofs can be flat. May be whitewashed for additional comfort by reducing heat gains	May be light weight but should be insulative; protection against heavy rainfall necessary
	External walls	Light weight, and thin, if possible, light external colours, Walls rain protected	Light weight, and thin, if possible, with short time lag for heat insulation. Light external colours, damp proofed	Light weight, local conditions may dictate, heavy walls, Light colours on wall	Careful consideration should be given to plan internal occupancy during hot summer months	May be thick with long heat transfer lag time	Light weight for heat insulation. Light external colours, damps proofed
Sub-structure	Technology	Twin pit toilet, septic tank toilet, EcoSan toilet, biodigester toilet, biogas-linked toilet	Twin-pit toilet, septic tank toilet, EcoSan toilet, biodigester toilet, biogas-linked toilet	Twin-pit toilet, septic tank toilet, EcoSan toilet, biodigester toilet, biogas-linked toilet	Twin pit toilet, septic tank toilet, EcoSan toilet, biodigester toilet, biogas-linked toilet	Twin-pit toilet, septic tank toilet, EcoSan toilet, biodigester toilet, biogas-linked toilet	Septic tank toilet, EcoSan toilet, biodigester toilet, biogas-linked toilet

Source: Compiled by CSE

Other factors that influence the selection include social and economic conditions of the beneficiary. The prime aim is to select a technology that is socially and financially acceptable, is ease to operate and maintain and has a low operation and maintenance cost.

However, several factors—such as insufficiency of trained masons, neglect of operation and maintenance, logistics, inadequate performance, inappropriate institutional framework, intermittent water service and non-involvement of communities—restrict the optimum functionality of on-site sanitation systems. These constraints may dilute the efficiency of on-site sanitation systems. The constraints impact the objective of sustainable sanitation as well as become the cause of environmental pollution as the danger of groundwater pollution from on-site sanitation should not be underestimated especially in case of the pit toilets. To avoid groundwater pollution, unsaturated sandy or loamy soil at least two metres deep is placed below the pit. This is likely to provide an effective barrier to groundwater pollution and prevent the lateral spread of pollution.

2.2 OPERATION AND MAINTENANCE OF ON-SITE SANITATION SYSTEMS

The appropriate operation and maintenance (O&M) strengthen the functionality of any on-site sanitation technology, however it is often neglected. Often, O&M is highly linked to ownership but it usually receives limited attention unlike the design and construction phases. Basic understanding of on-site sanitation (OSS) technologies characterizes the role and responsibilities of beneficiary to ensure proper O&M. It is noteworthy fact that for OSS technologies, the required O&M is very limited and for most of the cases can be managed at household level (*see Table 13: Do and don'ts for on-site sanitation technologies)*

Table 13: Do and don'ts for on-site sanitation technologies

Operation and maintenance	**On-site sanitation technologies**			
	Twin-pit toilet	**EcoSan toilet**	**Biogas-plant linked toilet**	**Septic tank**
Do's	• Keep a bucket full of water outside the toilet • Keep a 2 litre can filled with water inside the toilet for flushing • Before use, pour a little quantity of water to wet the pan • Flush after each use • Pan should be cleaned daily with a soft broom or soft brush with a long handle after sprinkling a small quantity of water and detergent powder/ soap • Wash hands with soap after defecation • If a construction defect is observed, fix it immediately • When the pit in use is full, divert the flow to the second pit • If the p-trap gets choked, rodding should be done from the pan side as well as from the rear side by means of a split bamboo stick, after removing the cover of the drain or junction chamber	• Keep a 1 litre can filled with water inside the toilet for anal cleaning • Use absorbent organic materialafter each use • Both drop holes (connected to two different chambers) should not be used simultaneously • Check proper connection of the urine-collection jerrycan with urine drop hole • Urine should be diluted before usage to agricultural fields • Wash hands, using soap after defecation • If a construction defect is observed, fix it immediately • When the first chamber in use is full, start using second drop hole connected to the second chamber • Do proper handholding for biosolids and urine reuse	• Keep sufficient water inside the toilet for flushing and cleaning • Before use, pour a little water to wet the pan • Flush after each use • Pan should be cleaned daily with a soft broom or soft brush with a long handle after sprinkling a small quantity of water and detergent powder/soap • Wash hands, using soap after defecation • If any construction defect is observed, fix it by professional immediately • Add feed material (cow dung) in biogas tank to initiate the digestion process • Ensure that feed (animal and human waste) for biogas tank is free from soil, straw, etc. • Use biogas near the biogas tank to ensure adequate pressure	• Keep sufficient water inside the toilet for flushing and cleaning • Before use, pour a little water to wet the pan • Flush after each use • Pan should be cleaned daily with a soft broom or soft brush with a long handle after sprinkling a small quantity of water and detergent powder/soap • Wash hands, using soap after defecation • If any construction defect is observed, fix it by professional immediately • Restrict entry of solid waste into the tank • Keep your septic tank cover accessible for inspections and pumping • Ensure safe removal of sludge from septic tank

Operation and maintenance	On-site sanitation technologies			
	Twin-pit toilet	**EcoSan toilet**	**Biogas-plant linked toilet**	**Septic tank**
Don'ts	• Do not use both the pits at the same time • Do not use more than 2 litres of water for each flushing • Do not use caustic soda or acid for cleaning the pan • Do not throw sweepings, vegetable or fruit peelings, rags, cotton waste, and cleaning materials like corn cobs, mud balls, stone pieces, leaves, etc. in the pan or the pits • Restrict the entry of rain water, kitchen or bath waste to pits • Do not desludge the pit before three months of not in use	• Do not use excess water for anal cleaning • Do not use intermix urine with faeces • Avoid overflow of urine collection jerry can • Do not use caustic soda or acid for cleaning the pan • Restrict entry of rainwater, kitchen or bath waste to pits • Do not desludge the pit before three months of disuse	• Do not undergo construction in waterlogged areas and in areas where soil should be hard (high bearing capacity). • Don't install the plant under a tree, inside the house or under shade • Don't leave the gas regulator (valve) open when the gas is not in use • Don't inhale the biogas as it may be hazardous. • Do not throw lighted cigarette butts in the pan • Avoid using chemicals/ detergents in cleaning toilet pans as it lowers activity of bacteria responsible for production of biogas • Restrict the entry of rain water, kitchen or bath waste to pits	• Restrict the entry of rainwater, kitchen or bath wastewater to pits • Don't use chemical drain cleaners or chemical-based cleaning products. • Don't access or enter a septic tank without proper safeguards • Don't use effluent from septic tank directly

Source: Compiled by CSE

If on-site treatment technologies work effectively (because of strong technical ground and proper O&M), further treatment of black water or faecal sludge is not required or is minimal. But this is seldom found to happen. The next chapters deal with the treatment options for black and grey water along with faecal sludge for rural India.

Chapter 3: DECENTRALIZED TECHNOLOGIES FOR TREATING WASTEWATER

KEY POINTS

- Wastewater from houses in rural settings is released from toilets, bathrooms and kitchens.
- Chapter 2 details how to treat black water coming out of the toilets by means of economic on-site processes.
- Assuming that rural areas can treat their black water, Chapter 3 details how to treat grey water coming out of kitchens and bathrooms.
- It compares different technologies and compares their performance and cost effectiveness.
- It also discusses the design parameters, operation and maintenance.
- Chapter 3 details how these technologies have been developed to effectively treat wastewater and use it for different purposes.

Wastewater in households is generated as a by-product of toilet usage, bathing and laundry, cooking, washing utensils and washing livestock. It serves as an excellent alternative to combat the water crisis as it is less chemically contaminated and requires less treatment than other treatment options. Assuming that rural India receive 55 litres of water per capita per day—as per the current norm—80 per cent of this water supplied is converted into wastewater. On the basis of the quantity of water supplied, rural India on an average generates about 31,000 million litres of wastewater daily.

At the household level, wastewater is usually categorized into grey water and black water, based on the source of generation. Grey water contains only about a tenth of the nitrogen found in black water. It has a much lower load of organic content and pathogens than black water. Wastewater is traditionally discharged in very unsafe ways, with indiscriminate open discharge into low-lying areas or waterbodies. This serves as a breeding ground for disease vectors and causes environmental pollution.

Wastewater (both black and grey) managed scientifically with appropriate technologies reduces the load on freshwater resources, invaluable in water-scarce areas. Treated wastewater acts as a potential source for irrigation, non-potable domestic use (washing and cleaning) and recharge of groundwater. Treatment can be provided at the household or at the community level.

3.1 TREATMENT OPTIONS AND DESIGN PARAMETERS

3.1.1 Leach pit or soak pit

Background:
A leach pit or soak pit is an underground chamber with or without filter material (usually stones or bricks) from where grey water infiltrates into the ground. It is the best option when there is no intention of reusing wastewater. The structures require less space than other on-site sanitation systems and needs low operation and maintenance.

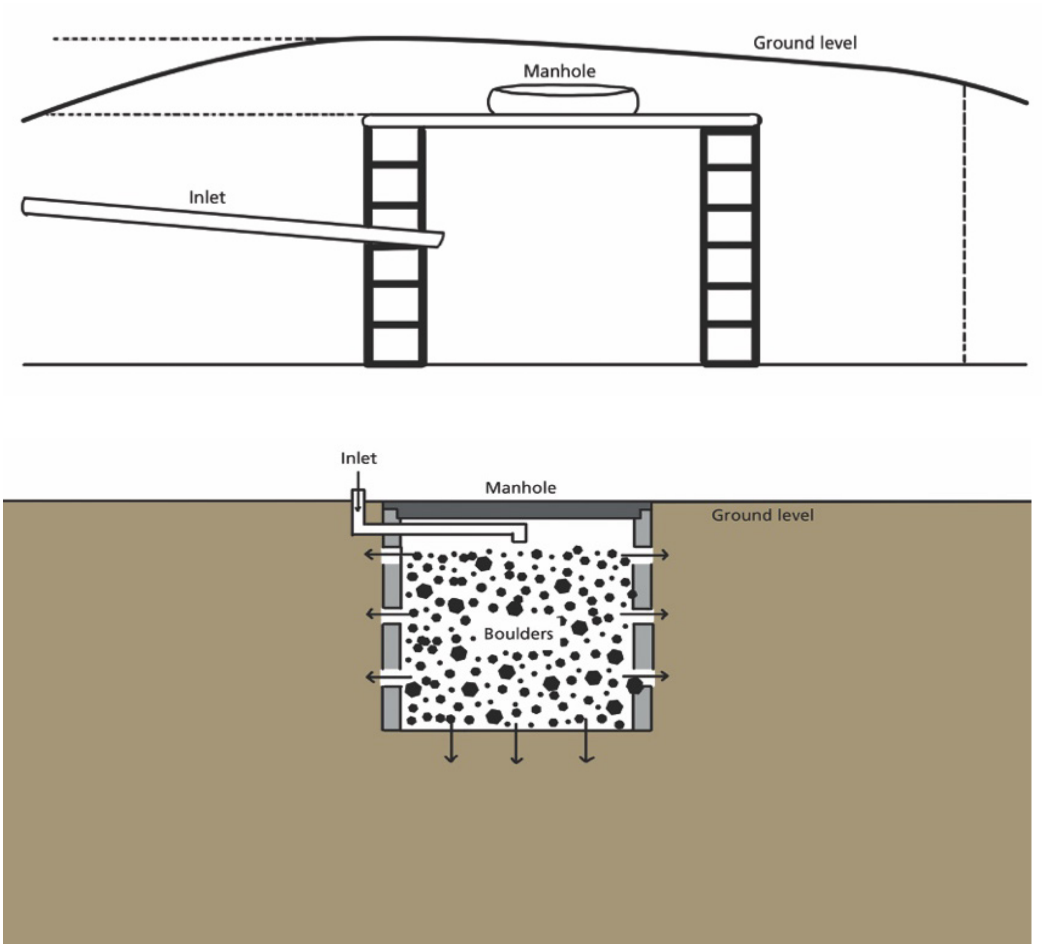
As grey water percolates into the ground through a leach pit, small suspended particles are filtered out by the soil matrix and organics are digested by microorganisms present in soil.

Leach pits are best suited for soil with good absorptive properties. They are not suitable for clay, hard-packed or rocky soil or flood-prone and waterlogged areas.

Design considerations:

- The bottom of the pit should be uncemented. The wall guard, made of locally available material, should be placed to prevent the collapse.
- The pit can be left empty and lined with a porous material to provide support and prevent collapse, or left unlined and filled with coarse rocks and gravel, which will prevent the walls from collapsing and provide adequate space for the wastewater.
- The material used to form the sidewalls of the pit should be made of porous and jointed material that permits leaching from the pit.
- For effective filtration, bricks, stones or boulders should place inside the pit.
- To ensure maintenance, a manhole is provided at the top.
- The surface the perimeter of the pit shall be raised to a height of at least 150 mm to avoid the entrance of rainwater into the pit.
- A well-sized soak pit should last three to five years without maintenance. To extend its life, care should be taken to ensure that the effluent has been clarified and/or filtered to prevent excessive buildup of solids.
- Soil permeability is a major requirement to avoid quick saturation. High daily volumes of discharged effluents should be avoided.
- The average size of leach pit is 1 m^3. The depth is 1.5–4 m, but as a rule of thumb never less than 2 m above the groundwater table.
- The structure should be located at a safe distance from a drinking-water source (ideally more than 30 m).

Figure 7: Design of leach pit and soak pit



Source: CSE

- Simple to build and maintain,
- Cost effective—locally available materials can be used for construction,
- Land requirement is low,
- Low capital and operating costs, and
- Can effectively recharge groundwater.

Box 9: Use of soak pits to manage grey water in Salwahan gram panchayat, Mandi, Himachal Pradesh

In Salwahan gram panchayat, every household manages their grey water by building soak pits. Located in Mandi district—declared in 2016 the cleanest hill district in Swachh Survekshan, a countrywide cleanliness survey by the Centre—this gram panchayat is setting new standards of cleanliness.

The work of constructing soak pits was started after the gram panchayat achieved Open-Defecation Free (ODF) status in 2017. A development fund of Rs 5,00,000 was provided by the government under the Swachh Bharat Mission (Gramin) to undertake solid and liquid resource management projects.

As there each household had ample space, beneficiaries made the soak pit near pipes discharging grey water in the premises of the households. The average size of the pit is 1 x 1 x 1 metre. They are small uncemented structures, filled with filter materials such as gravel, stone and boulders. After passing through the filter material the grey water recharges the groundwater.

In 2017, every household was connected to the soak pit. Creation of compost pits at the household levels not only made the villages look clean but also stopped water stagnation in the village.

VIKAS CHOUDHARY, CSE

Soak pit for grey water management at Salwahan gram panchayat, Mandi district

For details contact:
Sevak Singh,
District coordinator, Mandi Saksharta Evum Jan Vikas Samiti (NGO)

Phone: 9418164778,
Email: msjvsmandi@gmail.com

Source: CSE

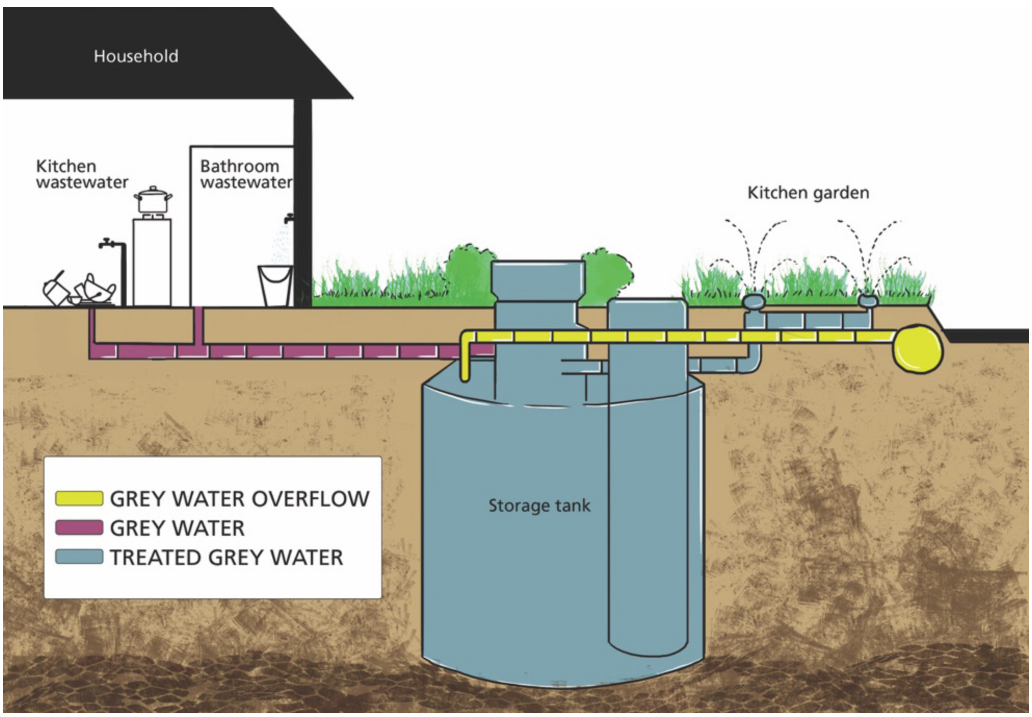
3.1.2 Kitchen gardens

Background:
Kitchen gardens are the most common way to use grey water at the household level. The outlet pipe containing grey water is discharged into the planted area in the vicinity of the household. Grey water passes through a perforated pipe laid into the planted bed. The plantation may be done in single or multiple rows depending on the available area. The bed prepared for the plants should have an additional bed of gravel to provide adequate surface area for the removal of organic compounds, suspended solids and excess nutrients. The removal is done through the combined effect of root zones and gravel beds, which include chemical, biological and physical mechanisms. The additional gravel bed will increase the residence time for the wastewater for better treatment—the wastewater will stay in the bed below the planted area so that the roots of the plants have longer to absorb nutrients. The roots of the plants will make the bedding medium porous and aerate the planted system.

Design considerations:
- Water-intensive plants should be avoided.
- The flow rate of grey water should be maintained in the planted bed to prevent nutrient shock. This can be done by collecting grey water into a PVC tank and controlling the flow from there.
- Pores of the discharge pipes should not be clogged with soil—for this the perforated pipes should pass only over the gravel bed.
- The flow of grey water should depend on the surface gradient to support smooth flow of grey water.

- Kitchen gardens are a low-cost solution to manage grey water,
- Plants grown in kitchen gardens get extra nutrients from grey water,
- Kitchen gardens reduce dependence on freshwater for gardening, and
- They are easy to maintain.

Figure 8: Design of a kitchen garden



Source: CSE

Box 10: Use of kitchen gardens for grey-water management in Gajapati, Odisha

'I don't rely any more on weekly haats (local market) for vegetables. My kitchen garden provides all the vegetables I need for my family,' says Surantini Gamanga, an accredited social health activist (ASHA) worker from Tuburda village in Gumma block in Gajapati, Odisha. Other families in Surantini's village in are now inspired to grow vegetables and fruits in their backyards.

With 24 hours of piped-water supply in every household becoming a reality in Gumma block, people in the village easily grow vegetables and fruit in kitchen gardens. They make good use of the grey water from each household by diverting it to the kitchen garden, thereby also supporting water conservation and soil rejuvenation. Families now eat more fruits and vegetables rich in nutrients. The families earn more as the crop yields have increased.

Kitchen gardens, locally referred to as Parasbaug, are an initiative by Ganjam district-based NGO Gram Vikas. 'Gram Vikas entered in our village in 2008. 'The idea of adding a kitchen garden to every house is to efficiently utilize grey water at the household level itself and to ensure that no one starves even if they live in abject poverty or in times of famine,' says Joe Mediath, founder of Gram Vikas.

Gram Vikas works with tribal communities and encourages them to conserve water and utilize the grey water from household activities to grow kitchen gardens. These complimentary kitchen gardens are established after toilet and bathroom are commissioned. Leafy vegetables, bulbs and roots, fruits and other green vegetables required for daily meals are cultivated in vacant spaces in the backyard of every household. The kitchen gardens are watered and fertilized from bathroom outlets and they get manure from the toilet soak pit.

RASHMI VERMA, CSE

Household-constructed kitchen garden to maintain grey water

For details contact:
Devi Prasad Mishra, Executive Director, Gram Vikas (NGO),

Address: Plot number 72/B, Forest Park, Bhubaneswar, Odisha

0674-2596366; 9898027221; 8280232398
sojan@gramvikas.org; info@gramvikas.org

Source: Compiled by CSE

3.1.3 Anaerobic baffle reactor

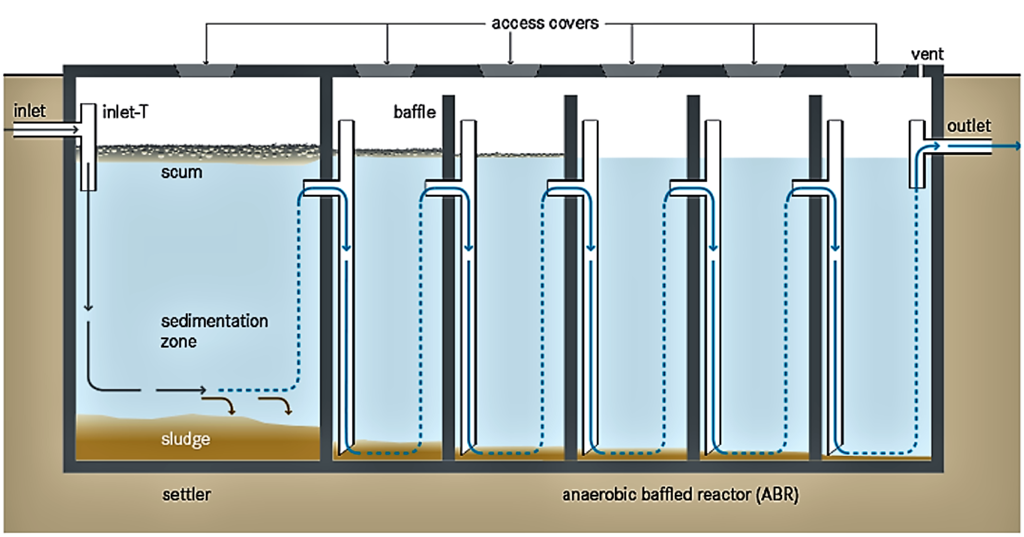
Background:
An anaerobic baffled reactor (ABR) is a simple linear reactor that has wide applications in the treatment of wastewater, black, grey or both. The working principal of an ABR is similar to that of a septic tank, i.e. physical treatment (i.e. settling of sludge) and a biological treatment (anaerobic digestion of accumulated sludge). Structurally, ABR consists of chambers or tanks with multiple baffles that compartmentalize the reactor. The pipe attached to the chamber helps wastewater flow up and down from one compartment to the next. This increases the contact time between wastewater and anaerobic

microorganisms present in the active biomass (cow dung) placed in each chamber. This results in enhanced removal and digestion of organic matter present in the wastewater (black, grey or both). ABRs are highly suitable for a wide range of wastewater, but their efficiency increases with higher organic load. Because of the cost effectiveness, low operational and energy requirements as well as mechanical simplicity, they are well suited for small-scale use in low-income areas.

Design considerations:

- Typical inflows of wastewater (black, grey or both) are in the range of 2–200 m^3 per day. Critical design parameters include a hydraulic retention time (HRT) of 10–48 hours (based on ambient temperature), upflow velocity of the wastewater below 0.6 m/hour and the number of upflow chambers (three to six).
- The connection between the chambers can be designed either with vertical pipes or baffles. Usually, the biogas produced in an ABR through anaerobic digestion is not collected because of its insufficient amount. The vent pipe should be placed in alternative chambers to allow controlled release of odorous and potentially harmful gases.
- In each chamber the cow dung should be added as active biomass to enhance microbial growth.
- The wastewater (black, grey or both) enters the chambers at the bottom and needs to pass to move up and to the next compartment.
- The sludge settles against the upstream. As the wastewater passes through the chamber, intensive contact between the active biomass in the resident sludge and newly incoming wastewater occurs.
- To equally distribute the liquid entering the chambers, the chambers should be designed as relatively short compartments (< 75 per cent of length and < 50 per cent to 60 per cent of the height).
- To retain any possible scum formed in the up-flow chamber, the outlets of each tank as well as the final outlet should be placed slightly below the liquid surface.
- The up-flow velocity is the most crucial parameter for dimensioning, especially with high hydraulic loading. It should not exceed 2 m/hour.
- Several materials can be used in the construction of an ABR. Metal, concrete and plastic are primarily used, depending on the setting. Concrete is a cost-effective and readily available construction material and is therefore a good option for remote and low-income locations. Readymade structures made up of plastics and metals such as alloys, stainless steels, and coated metals are more expensive but save on excavation costs.
- Provision of manholes on top of ABRs is considered as a must design accessibility option. The tank should be vented to allow for controlled release of odorous and potentially harmful gases.

Figure 9: Design of anaerobic baffle reactor



Source: Rohilla, S. et al. 2019, Integrated Wastewater and Faecal Sludge Management for Ghana: Draft Guidelines, Centre for Science and Environment

- Resistant to organic and hydraulic shock loads,
- No electrical energy is required,
- Low operating costs,
- Long service life,
- High reduction of BOD,
- Frequency of desludging is low as sludge produced here is mostly stabilized,
- Moderate area requirement (can be built underground also), and
- Simple to operate.

3.1.4 Waste stabilization ponds

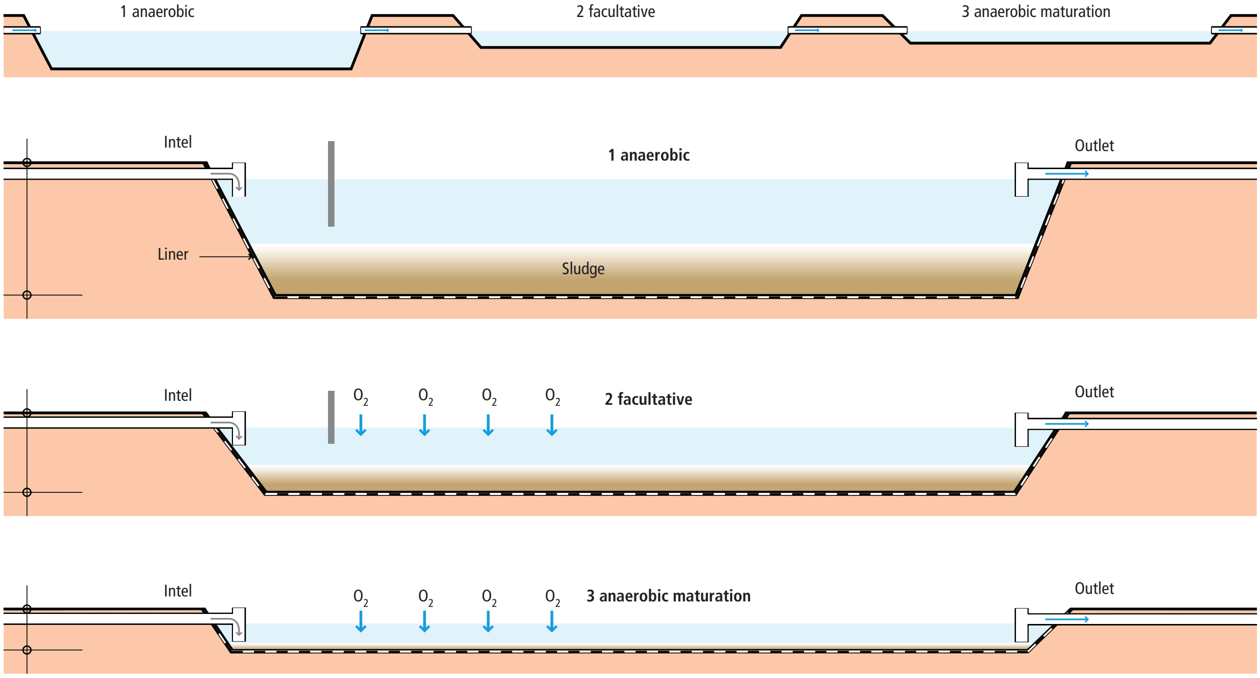
Background:
Waste stabilization ponds (WSP) are the community-scale wastewater treatment systems. They include natural or constructed ponds used for treating wastewater biologically. Wastewater passes through a series of ponds (anaerobic, facultative, and maturation ponds) with a total retention time of 10–50 days. Anaerobic and aerobic bacteria in the ponds degrade the organic waste and work symbiotically with algae, which provides oxygen through photosynthesis.

The major part of biodegradation of wastewater takes place in anaerobic ponds, which are 2–5 m deep and are nearly devoid of oxygen. Their retention time is one to seven days. Solids settle to the bottom, forming sludge, and anaerobic digestion takes place. Next to the anaerobic pond is a facultative pond, which is 1–1.5 m deep and provides retention time of five to 30 days. Solids settle to the bottom and both aerobic and anaerobic processes take places. Maturation ponds are placed after facultative ponds for the purpose of pathogen reduction. These are usually 0.5–1.5 m deep, with a retention time of 15–20 days. These ponds serve to inactivate pathogenic bacteria and viruses through the action of UV radiation from sunlight.

To avoid leaching and preserve wastewater for reuse, ponds are provided with liners. Liners can be made of clay, asphalt, compacted earth or any other impermeable material (i.e. material that does not let fluid pass through). The pond boundaries are safeguarded through proper fencing.

Design considerations:
- Ponds should be located at least 200 m downwind from the community they serve and away from any likely area of future expansion.
- The groundwater level should be determined beforehand. The groundwater level should not be less than 5 metres.
- For small pond systems, i.e. those serving less than 1,000 people, a form of preliminary wastewater treatment, such as screening and grit removal, prior to treatment in ponds, must be provided. However, bar screens (50 mm) remove large solids and provide additional support to the WSP.
- Anaerobic and primary facultative ponds should be rectangular, with length-to-breadth ratios of less than 3.
- The minimum freeboard that should be provided is decided on the basis of preventing waves induced by the wind from overtopping the embankment. Usually 0.5–1 m freeboard should be provided.
- Routine maintenance tasks (removal of screenings and grit, cutting the grass on the embankments, removal of floating scum and floating macrophytes, spraying the scum on anaerobic ponds, repair of damage to the embankments by rodents, rabbits or other animals, repair of damage to external fences and gates) should be undertaken regularly.
- Wastewater treated from a properly designed and well-maintained series of ponds is normally very suitable for reuse in crop irrigation.

Figure 10: Design of waste stabilization ponds



Source: Tilley, E. et al. 2014. Compendium of Sanitation Systems and Technologies. *Second revised edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland.*

Box 11: Village-level wastewater treatment by waste stabilization ponds in Karnal, Haryana

Chandsamand is a village situated in Indri Block of Karnal district, Haryana. It has a population of 2,248 and includes 415 households.

Management of wastewater in Chandsamand was a major problem, inviting public protest. Overflowing ponds and waterlogged streets due to improper disposal of wastewater was the usual scenario in their village.

Against this backdrop, the gram panchayat took up the project Three-Pond System, under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), to treat grey water and use it for gardening, kitchen gardening and irrigation.

In 2014, the district administration launched under the Nirmal Bharat Abhiyan—later restructured as Swachh Bharat Abhiyan—the project in Chandsamand village. The project was developed, designed and executed by the engineers of the Panchayati Raj department. The planning was handled by the executive engineer; the Panchayati Raj and the sarpanch initiated the execution. Apart from solving the problem of wastewater in villages, the project provided jobs to villagers under MGNREGS.

An area of 3 acres of land was covered by three ponds—the first pond was constructed over 1 acre, the second pond in 0.5 acre and the third one in 1.5 acre. Effluent from the first-stage anaerobic pond overflows into the secondary facultative pond, which comprises the second stage of biological treatment. A maturation pond provides tertiary treatment. The construction cost is approximately Rs 15–20 lakhs. The Three Ponds System caters to wastewater management of around 70 per cent households of the village.

Wastewater management in Chandsamand has contributed to its cleanliness. The Three-Pond System recharges the groundwater of the village. Treated sludge from the ponds is dug out and used as manure as well as a source of biomass for electricity generation. For the beautification of the ponds, a green belt was developed around them.

Waste stabilization pond at Chandsamand village

Source: https://www.panchayat.gov.in/documents/20126/0/3+pond+system+success+story.pdf/5ce08c2f-4e3f-4a7d-08ac-b1e41ade8bb9?t=1554984533380)

For details contact:
Babli Rani, Sarpanch,
Chandsamand Gram Panchayat
Karnal, Haryana

Phone: +91 9992797980

Source: Compiled by CSE

- No mechanical equipment is used in the ponds so O&M costs are low,
- The system is resistant to organic and hydraulic shock loads,
- High reduction of solids, BOD and pathogens present in the wastewater,
- High nutrient removal from the wastewater if combined with aquaculture,
- No electrical energy required, and
- No problem with flies or odour if designed and maintained correctly.

Box 12: How to calculate the volume of WSP

For a pond system comprising an anaerobic pond, a secondary facultative pond and a maturation pond, the following equations should be used:

$$Va = 0.5 \times P$$
$$Af = 30\ P/T$$
$$Am = Af$$

where: Va = anaerobic pond volume (m^3), Af = facultative pond area (m^2), Am = maturation pond area (m^2), P = Population, T = Ambient temperature (in degree centigrade)

These equations are based on a volumetric BOD loading of 100 g per m^3 per day on the anaerobic pond, which is assumed to achieve 40 per cent BOD removal.

The pond depths should be 3 m for the anaerobic pond and 1.5 m for the facultative and maturation ponds.

Source: WHO 1987. Waste Stabilization Ponds: Design Manual

3.1.5 Constructed wetlands

Background:
A constructed wetland is an engineered system, designed and constructed to utilize the natural functions of wetland vegetation, soils and their microbial populations to treat contaminants in wastewater. Complex, integrated systems, they consist of a properly designed basin that contains water, vascular plants and a substrate (usually sand, soils and/or gravel). Based on the flow of wastewater, constructed wetlands can be of following types: surface flow wetlands, subsurface flow wetlands and hybrid systems that incorporate surface and subsurface flow wetland. The extensive options in design, materials and technology allow the constructed wetland to be adapted to local conditions and land availability.

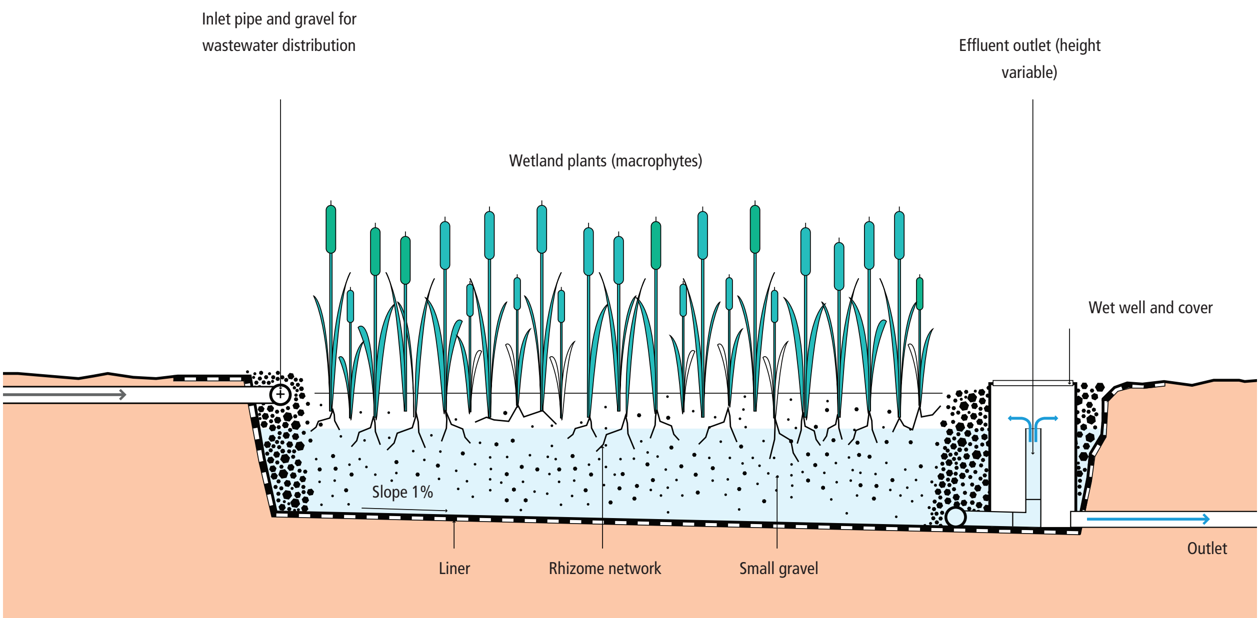
The general concept is that the plants, microorganisms and substrates together act as a filter and purification system. First, water is slowed down by the barrier provided by filtration materials (sand, gravel and boulders) and the plant root zone as it enters the wetland, allowing for sedimentation of solids. Through the process of water flowing through the constructed wetland, plant roots and the substrate remove the larger particles in the wastewater. Pollutants and nutrients in the wastewater are naturally broken down and taken up jointly by the bacteria (naturally residing on the roots of the plants) and the plants, thereby removing them from the wastewater.

The retention time of the wastewater in the wetland varies depends on various factors, including: a) design of the wetland, b) desired quality of the treated wastewaters, and c) UV radiation. After treatment in a constructed wetland, water can be safely released into the surface waters or used for various purposes like irrigation and non-potable uses. Treated wastewater can be drawn through outlets and used directly for irrigation or can be stored in tanks for other purposes.

Design considerations:
- Constructed wetlands are constructed by excavating, backfilling, grading, diking and installing water control structures to establish desired hydraulic flow patterns.
- Substrates used to construct wetlands include soil, sand, gravel, rock and organic materials such as compost.
- Constructed wetlands are usually planted with emergent vegetation (non-woody plants that grow with their roots in the substrate and their stems and leaves emerging from the water surface).
- Common plants include bulrushes, cattails, reeds and several broad-leaved species. These plants contribute to the treatment of wastewater and maintain the runoff in the wetlands in a number of ways: they stabilize substrates and limit channelized flow; they slow down the velocities of water allowing suspended materials to settle; take up carbon, nutrients, and trace elements and incorporate them into plant tissues, the root systems provide sites for microbial activity.

- Constructed wetlands must be sealed off to avoid possible contamination of groundwater and also to prevent groundwater from infiltrating into the wetland. Where on-site impermeable soils or clay provide an adequate seal, compaction of these materials may be sufficient to line the wetland. Sites underlined by fractured bedrock, or gravel or sandy soils will have to be sealed by some other method.
- Water levels are controlled by mechanical flow control structures. Flow control structures should be simple and easy to adjust.
- Inlets are usually simple: an open-end pipe, channel or gated pipe which releases water into the wetland. The distance above the water surface of the wetland is typically 12–24 inches. The use of coarse rock (3–6 inches, 8–16 cm) at the inlet and outlet points is done to avoid choking. This ensures rapid infiltration and prevents waterlogging and algal growth.

Figure 11: Design of constructed wetland



Source: Tilley, E. et al. 2014. Compendium of Sanitation Systems and Technologies. *Second revised edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland.*

- ➢ Cost effective in terms of construction and O&M,
- ➢ High treatment efficiency, especially for nitrogen,
- ➢ Communities can use this technology as it is simple to understand and manage,
- ➢ Construction can provide employment to local labourers,
- ➢ Natural processes utilized,
- ➢ Electricity generally only required for pumping water to storage facilities,
- ➢ Less expensive than similar systems (*see Table 15: Sustainability-influencing factors for community-based wastewater treatment technologies*),
- ➢ Tolerates fluctuations in the velocity of wastewater entering the system,
- ➢ Treated water can be reused for irrigation and other non-potable uses,
- ➢ Helps recharge groundwater and adds to surface-water level,
- ➢ Contributes to environmental protection by providing a habitat for plants and animals, and
- ➢ Pleasing natural aesthetics.

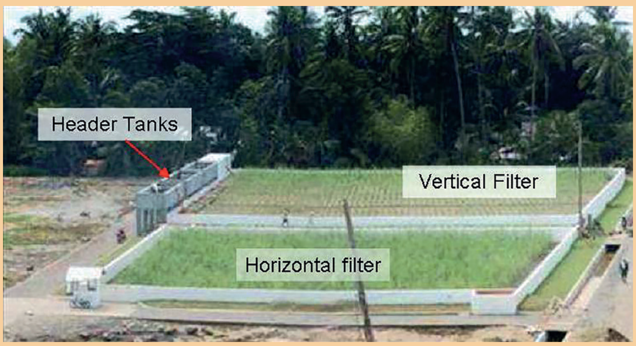
Box 13: Domestic wastewater treatment through constructed wetland in peri-urban housing area Bayawan City, Philippines

This project was planned to protect coastal waters from pollution with domestic wastewater and improve the health of residents through safe sanitation and wastewater treatment facilities. The project, designed for the population of 3,000 people, started in June 2005 in Bayawan City, Philippines. It was commissioned in September 2006. The total construction cost for the constructed wetland was about Rs 1.33 crore.

About the technology:
Most of the toilets are pour flush. Wastewater from toilets, bathrooms and kitchen sinks is partially treated in septic tanks, where solids are settled and the organic load is reduced. The wastewater is transported through a small-bore sewer system to the main sump for storage and solids removal. From the main sump, wastewater is pumped into four header tanks from where it flows by gravity into the vertical and horizontal flow constructed wetlands (soil filters).

The constructed wetland was designed for a flow rate of 50 litres per person per day for a total population of 3,000 people and a BOD concentration of 300 mg/l. Based on the design parameters, the calculated required area is: 1,800 m^2 for the vertical soil filter (cell 1) and 880 m^2 for the horizontal soil filter (cell 2). The dimensions are 48 m x 36 m and 33 m x 27 m, respectively. The total surface area is 2,680 m^2. The total depth of the filter basins is 2 m (cell 1) and 1.2 m (cell 2), including the drainage systems and about 0.6 m of free board. The filter layer (including sand, gravel and boulders) is 0.6 m in both cases. Water flows by gravity through the distribution system and a constant head assures an even distribution of the wastewater over the whole area of the cell. Both cells of the wetland are built of concrete and concrete blocks. The plants used in the filter are the local reed called tambok (*Phragmites karka*).

The system is operated manually, i.e. the pump is switched on and off and the header tanks are emptied into the distribution system. The header tanks are filled twice or thrice a day. The analysis of the treated wastewater showed very good pollutant removal efficiency (97 per cent removal of BOD). The treated wastewater is pumped from the effluent sump into an elevated storage tank and is used for irrigation, mainly in the cut flower and vegetable farming project of the Fishermen's Gawad Kalinga Village.



Constructed wetland in peri-urban housing area of Bayawan City, Philippines

For details contact:
Antonio Aguilar,
City Environmental and Natural Resources Office (ENRO)
Bayawan City,
Oriental Negros,
Philippines

E-mail: tons.aguilar@yahoo.com.ph

Source: https://www.susana.org/_resources/documents/default/2-51-en-susana-cs-philippines-bayawan-constr-wetlands-2009.pdf

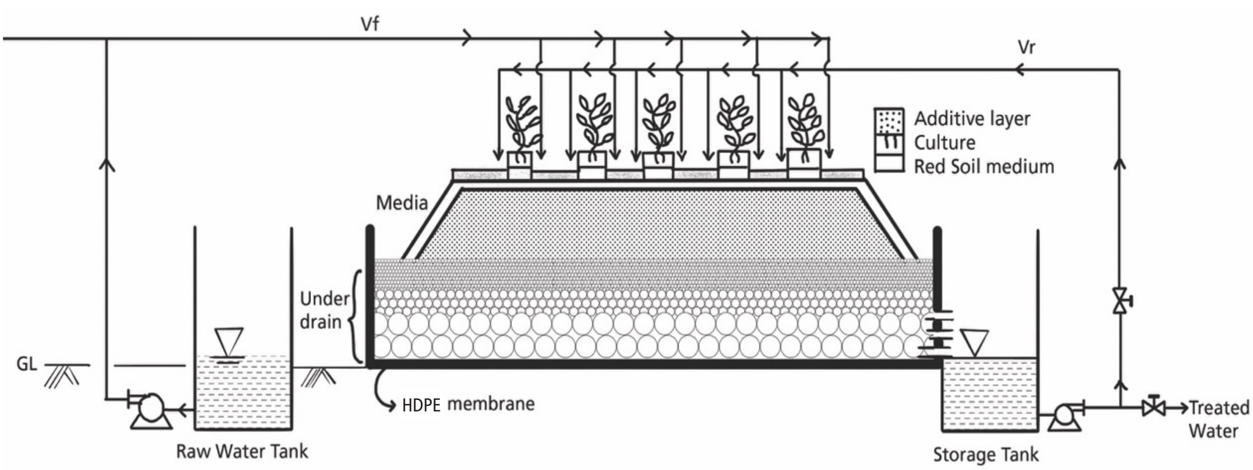
3.1.4 Soil biotechnology (SBT)

Background:
Soil biotechnology (SBT) is a terrestrial system for wastewater treatment based on the principle of the trickling filter. A combination of physical processes such as sedimentation and infiltration as well as biochemical processes are carried out to remove the suspended solids, organic and inorganic contents of the wastewater. SBT is an environment friendly waste-processing technology that offers systems for processing of both solid organic wastes and wastewater treatment using bacteria, earthworms and mineral additives in a garden-like setup. This technology was initially developed at the Indian Institute of Technology (IIT), Mumbai, after over two decades of research. Since it reinforces the carbon and nitrogen cycles in nature, it offers great efficiency and high-quality treated water.

Design considerations:
- SBT systems are constructed from RCC, stonemasonry or soil bunds. They comprise a raw-water tank, bioreactor containment, treated water tank, piping and pumps.
- Suitable mineral constitution, culture containing native microflora and bio-indicator plants are the key components of the system.
- The depth of impervious containment is 1.0–1.5 m below the ground.
- Wastewater is processed in an ecosystem consisting of soil-like media, bacterial culture, natural mineral additives and selected plants. Natural mineral additives are also used as a process regulator in order to archive desired treated water quality.
- The processes involve adsorption, filtration and biological reaction. The process operates in aerobic mode, thus eliminating the possibility of foul odour.
- The area is thus developed into a green belt, which easily integrates into any existing landscape.

- ➢ Wastewater is treated into usable output products,
- ➢ No sludge is produced,
- ➢ Water loss only by evapotranspiration from surface of filter—over 90 per cent recovery,
- ➢ Mechanization limited to effluent transfer/distribution pumps only,
- ➢ Process driven by natural aeration in engineered soil ecosystem—no external energy required for aeration, so energy conservative, and
- ➢ Operates quietly and thus can be located close to human habitation.

Figure 12: Design of soil biotechnology



Source: http://sugam.in/soilbiotechnology.html

Box 14: Soil biotechnology wastewater treatment plant at ACCEPT Society, Bengaluru

Bangalore-based non-profit Arghyam—supported by Mumbai-based Vision Earthcare Inc.—implemented soil biotechnology (SBT) on the campus of ACCEPT Society, an AIDS-care hospice on the outskirts of Bangalore. The project, commissioned in March 2011, commenced on August 2009.

The system is performing well. It provides treated wastewater for agricultural and horticultural activities on campus. The land required for the of 15 KLD (kilolitres per day) capacity soil biotechnology system was 120 square metres. The cost of construction was about Rs 19 lakhs (in 2010). This includes the cost of piping and electrical equipment to bring water in and out of the plant but does not include the cost of retrofits that were done to some of the equipment on campus or the cost of the 1 KLD test plant.

The annual power required for operating the system was found to be 1.06 unit/KL. Taking the 2010 cost of one unit electricity as Rs 7, the per day cost for treating 15 KL was calculated as Rs 111, which meant an annual power cost of Rs 40,624. Considering current situation, the O&M cost is approximately Rs 58,874. If the plant runs to full capacity, the cost of recycling 1KL comes to Rs 24.54.

About the technology:
The existing septic tanks (for black water) and soak pits (for grey water) enter into a different chamber (input tank), where mixing of black and grey water takes place. It also includes a chamber incorporated as a buffer storage space to account for any failures in the operation of the soil biotechnology. Two bioreactors of 15 KLD and 1 KLD capacities are constructed. An output tank is connected to the bioreactors and the treated wastewater is collected here. The bioreactor bed consists of granular media (soil, gravels and sand) and biological media (microbial consortium) and plants. PVC piping network connects all SBT components. The pipes are perforated at the edge to discharge the wastewater into the bioreactor. The submersible pump resides to pump the treated wastewater for irrigation purpose. The treated wastewater from SBT has the potential to meet the high water-quality standards for use in agriculture as well as water for toilet flushing and discharge to rivers and waterbodies. It is a green technology, which uses less power and discharges no methane as part of the treatment process.

For details contact:
Dr S. Chandrashekar, Vision Earth Care
Address: Vision Earthcare Pvt. Ltd,
Shop 1 Neel Empire Bldg,
Plot 3A/4, Sector 25,
Nerul,
Navi Mumbai 400706

Contact number: +91 22 27718444
Email: contactus@visionearthcare.com

Source: Compiled by CSE

Table 14: Proposed treatment options for wastewater at the household and neighborhood levels in rural India

Type of treatment	Scale	Description	Advantages	Suitability
Leach pit	Individual household	• Planned only for wastewater from kitchen and bathroom • Brick-lined single circular pit using honeycomb masonry • Diameter of pit approximately 1 metre • Wastewater percolates into the ground • Pit to have insect-proof cover with inlet pipe using a water-seal trap to avoid mosquito breeding	• Can handle larger volumes of water than a traditional soak pit • Prevents water stagnation • Prevents vector breeding • Can be managed easily by household owner	• Suitable in areas where groundwater is deep
Kitchen garden	Individual household	• Planned only for wastewater from kitchen and bathroom • Wastewater is passed through a silt and grease trap to remove debris and into a simple surface irrigation system or into a piped root zone water system • The root system has the added feature of a filter bed around the PVC pipes which further filters the water before it reaches the plants.	• Simple and cost-effective technology • Prevents water stagnation • Prevents vector breeding • Supports growth of plants • Can be managed easily by the household owner	• Suitable in any type of soil
Anaerobic baffle reactor	Community	• Wastewater passed through series of reinforced cement concrete (RCC), stone-masonry tanks (three or more) brought through locally laid drainage lines • Drainage system may carry both black and grey water or either to the system • Treatment takes place by microbial activity	• Treated water can be stored and used when needed	• Suitable in small towns where cost is not a constraint
Waste stabilization ponds (WSP)	Community	• Wastewater from local laid out drainage system passed through large shallow basins or ponds placed in a series • Drainage system may carry both black and grey water or either of them to the system	• Capital cost is very low • Natural process operation and maintenance cost is low • Can be managed by the community	• Suitable in areas where groundwater is deep

Type of treatment	Scale	Description	Advantages	Suitability
Constructed wetland	Community	• Wastewater from local laid out drainage system passed into the wetlands • Drainage system may carry both black and grey water or either of them to the system • The wastewater into the wetland has to be channelized within the wetland and water may be sprayed vertically or horizontally *(see Figure 10: Design of constructed wetland)* • Masonry or natural structures planted with wetland plants and supported by gravel and boulders at the bottom • The process uses natural biological process of plants and soil to clean water	• Is technically simple • Is ecologically sustainable • Can handle large variety of pollutants	• Suitable in rural areas. In areas prone to water-logging, the base of the wetlands should be structurally modified
Soil biotech-nology	Community	• Wastewater from local laid-out drainage system passed into the system • Drainage system may carry both black and grey water or either one of them to the system • RCC, stonemasonry or soil bunds and consists of an impervious containment • An under-drain layer lies at the bottom above which lies a layer of media housing microbial culture and plants • Physical (like sedimentation, infiltration) and biochemical processes are carried out to treat wastewater	• No sludge production • No odour • Duration of treatment is small • Treated water can be stored and used when needed • Considered as one of the most efficient treatment technologies	• Suitable in small towns, where cost is not a constraint

Source: Compiled by CSE

Table 15: Sustainability-influencing factors for community-based wastewater treatment technologies

Issue category	ABR	WSP	Constructed wetland	Soil biotechnology
Environmental protection	• Effective in removing organic matter, might need finishing stage; • No nutrient removal; Must be followed by post-processing for this purpose	• Effective in removing organic matter and slight removal of nutrients and pathogens	• Effective in removing organic matter and nutrients. Must be followed by post-processing for pathogen removal	• Effective in removing organic matter, nutrients and pathogens
Human and ecosystem health	• Effluent usually needs a post-processing. Treated wastewater needs to be disinfected before further use	• Effective integration with existing ecosystems. Treated wastewater needs to be disinfected before further use	• Effective integration with existing ecosystems. Treated wastewater needs to be disinfected before further use	• No such need
Resources conservation	• Ready to fit structures are available. Energy efficient. Effluent and excess sludge high in nutrients (could be used in agriculture). Sludge can be processed for nutrient recovery	• Treated effluent can be used in irrigation. Sludge can be processed for nutrient recovery. Energy efficient	• Treated effluent can be used in irrigation. Energy efficient	• Ready to fit structures are available. Effluent can be used in irrigation. Energy efficient, small amount required for pumping to storage tanks
Investment	• Low, especially for physical infrastructure. Existing drainage carrying wastewater is a mandate	• Land requirement is high and also there is a need of a drainage system carrying wastewater	• Land requirement is high and also there is a need of a drainage system carrying wastewater	• Land requirement is high and also there is a need of a drainage system carrying wastewater
Efficiency (technology)	• Cost of technology per unit organic pollutant removed is low. • Robustness of technology medium-high	• Cost of technology per unit organic pollutant removed is low. • Robustness of technology low	• Cost of technology per unit organic pollutant removed is low. • Robustness of technology is low	• Cost of technology per unit organic pollutant removed is low. • Robustness of technology high
Residuals management	• Very low sludge production	• Ample sludge production in anaerobic pond	• Sludge must be periodically removed and disposed. Depending on the type of planted vegetation, the biomass can be processed for recovery of energy/ material	• Sludge must be periodically removed and disposed. Depending on the type of planted vegetation, the biomass can be processed for recovery of energy/ material

Source: Compiled by CSE

3.2 OPERATION AND MAINTENANCE—DO'S AND DON'TS

Table 16: Operation and maintenance—Do's and don'ts

	Leach pits	Kitchen garden	WSP	ABR	Constructed wetland	Soil biotechnology
Do's	• Keep constant check on manhole over the leach pit • Do biannual cleaning of leach pit	• Keep constant check over PVC pipe connection and other components • Provide proper flow of wastewater into the plant root zone	• Periodic cleaning of ponds surface • Appropriate check on fence and door safeguarding the edges of the ponds • Proper check over the drainage system • Assured reuse of the treated wastewater • Proper quality check before reuse of treated wastewater • Desludging of anaerobic pond should be done on regular basis • If the water is reused for irrigation, the salinity of the effluent should be controlled by mixing the effluent with fresh water	• Put cow dung to fasten the microbial activity before commissioning • Constant check on civil structures and pipelines • Desludging of chambers should be done on regular basis • Ensured reuse of the treated wastewater • Proper quality check before reuse of treated wastewater	• Wastewater flow should be checked regularly to avoid flooding • Use locally available plants • Do proper cleaning at the constructed wetland surface biannually • Ensured reuse of the treated wastewater • Proper quality check before reuse of treated wastewater	• Proper check of PVC pipes • Use locally available plants • Ensured reuse of the treated wastewater • Proper quality check before reuse of treated wastewater
Don'ts	• The connection of downpipe from rooftop should not be put in the leach pit	• Don't use harsh chemicals and detergent in kitchen • Any solid material like plastic etc. should not be put into the pipe	• Avoid entrance of solid material like plastic etc. • Avoid mixing of treated wastewater with open wells • Delimits direct exposure to human and animal	• Don't use any harsh chemicals and detergent in toilet cleaning • Avoid mixing of treated wastewater with open wells • Avoid entrance of solid material such as plastic etc. • Unskilled labour should be avoided • Exposure to harmful gases should be avoided by wearing safety gears	• Avoid entrance of solid material like plastic etc.	• Avoid entrance of solid material like plastic etc.

Source: Compiled by CSE

Chapter 4: REUSE OF TREATED WASTEWATER

KEY POINTS:

- Around 80 per cent of India's water is used for irrigation. There is huge scope for reuse of treated wastewater in the agriculture sector in rural areas.
- Treated wastewater can also be used for aquaculture and non-potable uses like flushing.
- It is very important that wastewater is treated to a standard that will make it safe for users.
- A centralized national policy for reuse of treated wastewater is the need of the hour. Only two states—Gujarat and Haryana—have state-level policies so far.
- The Central Public Health and Environmental Engineering Organisation has come up with a standard of treated wastewater that can be reused.
- This chapter underscores and explains how wastewater treated with appropriate technologies increases the quality and yield of vegetables and can reduce to a large extent the use of chemical fertilizers. Increase in fish yields and improvement of the varieties can also be seen if treated wastewater is used for pisciculture.

Treated wastewater can be a substitute for freshwater as it can contribute to meeting irrigation and other non-potable needs. When it serves as a source of irrigation, it helps increase food production by supplying nutrients to plants and reducing the need for chemical fertilizers.

However, if used without treatment for irrigation or other non-potable uses, wastewater poses serious risks to human and environmental health. Health risks due to worms and transmission of faecal bacterial diseases include intestinal infections—diarrhoea, dysentery, typhoid and cholera—to agricultural workers in wastewater-irrigated fields and to consumers of wastewater-irrigated produce.

These risks may be minimized by suitably treating wastewater. The previous chapters deal with technologies to effectively treat black and grey water so it can be reused in agriculture and other non-potable purposes.

4.1 EXISTING POLICIES AND REGULATIONS FOR TREATED WASTEWATER AND ITS REUSE

International agencies such as the World Health Organization (WHO), US Environmental Protection Agency (USEPA) and World Bank have reviewed the health risks associated with the public use of wastewater for crop irrigation.[13] According to recommendations, microorganisms in wastewater used for irrigation of crop plants should not be more than 1,000 faecal coliform per 100 ml. Rules and regulations regarding use of sewage water varies from country to country. In India, for example, there is huge scope for the formulation of national policy for the reuse of wastewater where consumption is largely for irrigation. A massive push is needed to prioritize for wastewater treatment, recycling and reuse.

Since water and sanitation are state subjects, states need to formulate their policies as per their requirements following the centralized policy guideline. Indian states such as Gujarat and Haryana have formulated policy guidelines to promote use of treated wastewater in urban areas. The government of Gujarat's policy, Reuse of Treated Waste Water Policy, 2018, aims to promote the use of wastewater treated at sewage treatment plants in all major towns and cities of Gujarat, thereby reducing the dependence on freshwater sources such as the Narmada River. Since the policy is for urban areas, the focus is on setting up sewage treatment plants in all major towns and cities of Gujarat. The state government of Haryana issued in October 2019 the Reuse of Treated Waste Water Policy to maximize collection and treatment of sewage generated and reuse wastewater treated at sewage treatment plants on a sustainable basis, thereby reducing dependence on freshwater resources and promoting treated wastewater as an economic resource.

In view of increasing drought events and related water scarcity, the government has published several policy documents to promote water conservation, efficient water use, and reuse and recycling. There is a clear dearth of adequate guidelines for reuse of treated wastewater although the Water (Prevention and

Control of Pollution) Act (1974) mandated the discharge of treated wastewater in the 1970s. The Central Pollution Control Board (CPCB) and MoEF&CC enforced the discharge parameters for wastewater (*see Table 14: Wastewater discharge standards by CPCB and MoEF&CC*). The National Water Policy of 2012 promotes recycling and reuse of water after treatment to specified standards as well as preferential tariffs that incentivize treated wastewater over freshwater. The National Urban Sanitation Policy (NUSP) of 2008 addresses reuse of wastewater as an important factor in helping meet the environmental targets of the city. The NUSP recommends the Service Level Benchmarks defined by the Ministry of Urban Development (MoUD) and recommends a minimum of 20 per cent reuse of wastewater in every city. However, specific guidelines for implementation of the policies is missing in all cases. In the absence of specific standards and guidelines, wastewater is reused for irrigation in an informal way all over India, often with negative consequences. In several parts of the country, local governments earn revenue by selling treated or untreated sewage to local farmers; there are many instances of industries selling or giving away their treated effluent to local farmers as well.

The standards for treated wastewater that can be reused were presented by the Central Public Health and Environmental Engineering Organisation (CPHEEO)[14] (*see Table 17: Wastewater discharge standards by CPCB and MoEF&CC* and *Table 18: Standards for treated wastewater for reuse with focus on urban areas by CPHEEO*). The standards were set for use of treated wasterwater in urban areas and omitted standards for heavy metals.

The key points for a successful water reuse programme in rural areas should include reliable treatment to meet wastewater quality requirements for reuse, protection of public health and environment, and public acceptance.

Table 17: Wastewater discharge standards by CPCB, MoEF&CC and NGT

Parameters (units are in mg/l except pH, FC in MPN/100ml)	Standards as per CPCB (updated on April 2015)	Revised by MoEF&CC (Gazette Notification dated October 2017)	NGT order 2019 (for mega and metropolitan cities)
pH	6.5–9	6.5–9	-
Biological oxygen demand	< 10	20–30	< 10
Chemical oxygen demand	< 50	-	< 50
Suspended solids	< 10	< 50–100	< 20
Ammonical nitrogen	< 5	-	< 10
Phosphate	< 2	-	< 1
Total nitrogen	< 10	-	-
Faecal coliform (FC)	< 100	< 1000	Permissible < 230

Source: NGT 2019, MoEFCC 1986, 2015 and 2017

Table 18: Standards for treated wastewater for reuse with focus on urban areas by CPHEEO

S. no	Parameter	Reuse for toilet flushing, horticulture and other non-potable uses
1	Turbidity	< 2
2	Suspended solids	Nil
3	Total dissolved solids	< 2,100 mg/l
4	pH	6.5–8.3
5	Minimum residual chlorine	1 mg/l
6	Total kjeldahl nitrogen	< 10 mg/l
7	Biological oxygen demand	< 10 mg/l
8	Dissolved phosphorus	< 1 mg/l
9	Nitrate	< 10 mg/l
10	Faecal coliform (MPN/100ml)	Nil

Source: CPHEEO

A lack of comprehensive standards and policy framework at the national level is hindering the development of a formal market, appropriate technology and sustainable business/financial models. In addition to comprehensive standards by the Central government, local Water Users' Authorities (WUA) comprising diverse stakeholders can be established to set tariffs and monitor allocation and use as suggested by the National Water Policy.

4.2 USING TREATED WASTEWATER

The use of wastewater use in agriculture is an age-old practice. Where freshwater is scarce, wastewater serves as a reliable source of water for non-potable purposes. The high nutrient content of the treated wastewater makes it a preferable water source that can help reduce input costs (i.e. chemical fertilizers).

But the ever-changing composition of wastewater produced makes its treatment crucial. Wastewater used in irrigation without proper treatment is hazardous to plants, soil and groundwater. It affects the quality of groundwater resources in the long run—the excess nutrients and salts will leach below the plant root zone and impact soil structure (*see Table 19: Potential impact on agriculture due to use of untreated wastewater*).

Table 19: Potential impact on agriculture due to use of untreated wastewater

Contaminant	Parameter	Impacts
Plant nutrients	N, P, K	Excess N causes plant injury, delayed growing season and maturity, and can cause economic loss to farmers; excessive amounts of N and P can cause excessive growth of undesirable plant species; nitrogen leaching causes groundwater pollution with adverse health and environmental impacts
Suspended solids	Volatile compounds, suspended and settleable solids	Development of sludge deposits causing anaerobic condition; plugging of irrigation equipment and systems such as sprinklers
Pathogens	Virus, bacteria, helminthes, fecal coliform	Cause communicable disease
Organic matter	BOD, COD	Depletion of dissolved oxygen in surface water; development of septic conditions; excess humus build-up
Stable organic compounds	Phenols, pesticides, chlorinated hydrocarbons	Persist in the environment for long periods; toxic to environment
Dissolved inorganic compounds	TDS, EC, Na, Ca, Mg	Cause salinity and associated adverse impacts; affects permeability and soil structure
Heavy metals	Cd, Pb, Ni, Zn, As, Hg	Bioaccumulates in plants; accumulates in irrigated soils and the environment; toxic to plants; systemic uptake by plants lead to subsequent ingestion by humans or animals; possible health impacts
Residual chlorine	Free and combined chlorine	Leaf-tip burn; groundwater and surface water contamination

Source: Hussain I., et al. 2002. Wastewater use in agriculture: Review of impacts and methodological issues in valuing impacts. Working Paper 37. Colombo, Sri Lanka: International Water Management Institute. (https://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR37.pdf)

The treatment technology to be adopted to use wastewater in agriculture depends on the nature of crops, local conditions and regulatory framework. If wastewater reuse is specifically for agriculture, the cost associated with the treatment system must be justifiable with regard to the value of the crop, degree of water scarcity, and public concern. There are several advantages of using treated wastewater in agriculture, including water conservation (by recycling and groundwater recharge), conservation of soil nutrients (reducing need for chemical fertilizer) resulting in increase in crop yields and crop density. Treated wastewater provides a sustainable source of water to farmers even in the lean season. The Food and Agriculture Organization of the United Nations (FAO),[15] has provided a guideline on the treated wastewater quality which can be used for irrigation (*see Table 20: Treated wastewater quality for irrigation*).

Table 20: Treated wastewater quality for irrigation

Parameter	Irrigation method	Unit	Degree of restriction on use		
			None	Slight to moderate	Severe
pH	Any local irrigation method		Normal range 6.5–8		
Salinity (EC)	Any local irrigation method	dS/m	< 0.7	0.7–3	> 3.0
TDS	Any local irrigation method	mg/l	< 450	450–2,000	> 2,000
TSS	Any local irrigation method	mg/l	< 50	50–100	> 100
Sodium	Sprinkler irrigation	meq/l	< 3	> 3	
Sodium	Surface irrigation	meq/l	< 3	3–9	> 9
Chloride	Sprinkler irrigation	meq/l	< 3	>3	
Chloride	Surface irrigation	meq/l	< 4	4–10	> 10
Chlorine	Total residual	mg/l	< 1	1–5	> 5
Bicarbonates	Any local irrigation method	mg/l	< 90	90–500	> 500
Boron	Any local irrigation method	mg/l	< 0.7	0.7–3	> 3
Hydrogen sulfide	Any local irrigation method	mg/l	< 0.5	0.5–2.0	> 2
Iron	Drip irrigation	mg/l	< 0.1	0.1–1.5	> 1.5
Manganese	Drip irrigation	mg/l	< 0.1	0.1–1.5	> 1.5
Total nitrogen	Any local irrigation method	mg/l	< 5	5–30	> 30

Source: Tanji KK, Kielen NC (2002). Agricultural Drainage Water Quality Management in Arid and Semi Arid Areas. Rome, Food and Agriculture Organization of United Nation (FAO Irrigation and Drainage Paper No. 61)

Apart from agriculture, treated wastewater can also be a potential source for aquaculture and pisciculture. For instance, the east Kolkata sewage fisheries are the largest single wastewater-use system in aquaculture in the world.[16] But the wastewater here is naturally bio-remediated by exposure to the sunlight. Although exposure to sunlight is a good practice, heavy metals and pesticides often present in wastewater may lead to bioaccumulation in aquaculture or pisciculture. Therefore, proper treatment is required before commissioning any aquaculture activities. Studies show that treated wastewater used for aquaculture give high productivity of tilapia fish.[17] A wide range of fish species are suggested to be most suitable to cultivate in aquaculture ponds receiving treated wastewater. This includes common carp (*Cyprinùs carpio*), Indian major carps (*Catla catlax, Cirrhina mrigala* and *Labeo rohita*), Chinese silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp, crucian carp (*Carassius auratus*), Nile carp (Osteochilus hasseltii), and tilapia (*Oreochromis spp*.).

Box 15: Impact of use of treated wastewater on crop yield in southern Italy

The use of treated wastewater for crop irrigation is the best option for the countries in the Mediterranean region, characterized by frequent droughts. Any use of groundwater for irrigation causes a fall in already declining groundwater levels.[18]

A study conducted in southern Italy (the Apulia region) in 2016–18 evaluated the effect of irrigation with treated wastewater on soil properties and crops yield. Treated wastewater was used to irrigate tomato and broccoli, cultivated in succession. The irrigated soils, plants and crop products were analysed for the main physicochemical characteristics and faecal indicators.

The result of the study showed that irrigation with treated wastewater did not significantly affect the marketable yield and the qualitative traits of tomato and broccoli crops. Further, E. coli or faecal coliform were not reported from any sample of soil, plant or crop product, probably due to their rapid die-off while passing through the filter material.

The drip irrigation system used avoids close contact between water and plant and may have contributed to this. Under the conditions applied in this study, the reuse of treated wastewater for irrigation can be considered an effective way to cope with agricultural water shortage in the Mediterranean region.

Source: Compiled by CSE

Box 16: Wastewater treatment and reuse in Indradhanushya Centre, Pune, Maharashtra

A wastewater treatment system was installed for a flowing stream alongside the Indradhanushya Environment Education and Citizenship Centre in Pune, Maharashtra. Construction started in 2015 and the project was commissioned in 2016. The project covers a population of around 250 people. The capacity of treatment plant is 50 KLD. The wastewater is lifted from the stream carrying domestic wastewater from the city. The total investment was Rs 40,00,000.

Eco-filtration bank (EFB) technology, a horizontal filtration technique, was proposed to be the main technology. It comprises a screen, intake well, sub-surface biofilter (a type of constructed wetland), and a treated water pond. About 50 m^3/day of wastewater from the stream was diverted into the intake well and treated in the subsurface biofilter bed to yield approximately 40 m^3/day of clean water for gardening and flushing the toilet.

The treated effluent (40 m^3/day) is stored in a water tank (of 60 KLD capacity) and used mostly for gardening. Any excess water is used for flushing. The green cover at the Indradhanushya Centre as well as the Sachin Tendulkar Jogging Track—opposite the Indradhanushya Centre—was maintained through treated wastewater from this tank—around 12 m^3/day and 15 m^3/day of water respectively are utilized. The remaining 10–15 m^3/day of treated water is used for toilet flushing in the area adjacent to the Indradhanushya building. The system thus saves around 40 m^3 of freshwater every day.

The cost economics under existing conditions indicates that the present cost of freshwater is Rs 11,800/day per 50 m^3 and cost incurred for generating non-potable recyclable water for 50 m^3 is Rs 800/day. Therefore, the net savings in respect to flushing and gardening would be Rs 11,000/day. This would ensure savings of Rs 40,00,000 per annum from a 50 m^3/day capacity wastewater treatment plant.

For details contact:

Pallavi Patil, Environment Executive
Shrishti Eco-Research Institute (SERI) B-106, Devgiri,
Opp. P.L. Deshpande Garden,
Near Ganesh Mala,
Sinhagad Road,
Pune,
Maharasthtra

Phone number: +020 24253773
Email: seriecotech@yahoo.co.in; contact@seriecotech.com

Source: https://www.susana.org/_resources/documents/default/3-2436-7-1454944035.pdf

Chapter 5: REUSE OF TREATED FAECAL SLUDGE

KEY POINTS:

- Where appropriate technologies are not followed, on-site sanitation systems produce untreated or partially treated sludge.
- Untreated or partially treated sludge when disposed of to land and water contaminate soil, groundwater and surface water, but when treated can produce organic manure.
- There are several instances where faecal sludge treated with different methods produce manure that increases agriculture produce.
- Because of the absence of legislation and monitoring mechanism in India, this sector has not been explored as it should have been.
- There are no guidelines or specifications for the use of treated sludge in the agricultural sector in our country. The closest to a guideline is the Fertilizer (Control) Order 1985, which is generally followed.[19]

In developing countries, on-site sanitation facilities (twin pit toilets, septic tanks, EcoSan, biodigester toilets etc.) are in place to help achieve sustainable sanitation (refer to Chapter 2). But where appropriate design specifications are not followed, on-site sanitation systems become a store for accumulation of excreta and necessitate periodical cleaning and disposal or treatment of semi-treated or untreated faecal sludge. This partially digested or undigested excreta matter is nutrient-rich and contains a high amount of organic matter, which acts as organic manure for agricultural production (*see Table 21: Characteristics of faecal sludge in tropical countries*).

Table 21: Characteristics of faecal sludge in tropical countries

Parameter	Type A high strength	Type B low strength
Characteristics	Highly concentrated, mostly fresh faecal sludge; stored for days or weeks only	Faecal sludge of low concentration; usually stored for several years; more stabilized than Type A
COD mg/l	20–50,000	< 15,000
COD/BOD	5:1 to 10:1	5:1 to 10:1
NH_4 mg/l	2–5,000	< 1,000
TS mg/l	≥ 3.5 %	< 3%
SS mg/l	≥ 30,000	7,000 (approx.)
Number of helminth eggs	20–60,000	4,000 (approx.)

Source: Strauss, M., Larmie, S.A. (1997). Treatment of sludges from on-site sanitation—low-cost options. Water Science and Technology 35(6) p.129–36.

Despite having high nutritive value, faecal sludge cannot be acceptable because of the presence of high concentrations of infectious microorganisms, toxic metals and chemicals. The survival of the several types of pathogens in faecal sludge varies (*see Table 22: Survival of pathogens in faecal sludge in different environments*). Due to the long shelf life in faecal sludge, it causes more harm than other on-site sanitation systems to human health and the environment. Appropriate treatment for faecal sludge is therefore a prerequisite for planning for its reuse.

Table 22: Survival of pathogens in faecal sludge in different environments

Type of pathogen	Survival time in days (value in bracket shows the normal survival time)
Enteroviruses	< 100 (< 20)
Faecal coliforms	< 90 (< 50)
Salmonella spp.	< 60 (< 30)
Shigella spp.	< 30 (< 10)
Vibrio cholerae	< 30 (< 5)
Entamoebahystolytica cysts	< 30 (< 15)
Asscaris-lumbriocoides eggs	Many months

Source: Feachem, R.G., Bradley, D.J., Garelick, H., Mara, D.D. (1983). Sanitation and Disease. Health aspects of excreta and wastewater management. World Bank studies in water supply and sanitation. John Wiley and Sons. New York.

In physical appearance, faecal sludge is semi-liquid and consists of suspended, colloidal and dissolved organic and inorganic matter. The normal treatment of faecal sludge involves separation of solid and liquid. This minimizes the total volume to be handled and biological treatment or heat treatment (drying and incineration) for stabilization. Vacuum filtration, pressure filtration, belt press filter etc. are used for dewatering of sludge.

The character of the treated faecal sludge depends upon its origin, the amount of ageing that has taken place at the on-site sanitation level, and the type of treatment process to which it has been subjected.

5.1 EXISTING REGULATIONS FOR REUSE OF FAECAL SLUDGE

Faecal sludge management in India is especially a big challenge due to rapid urbanization and economic growth. Sludge management—categorized as management of unhazardous waste—is governed by the Municipal Solid Waste (MSW) Handling Rules, 2000, and is restricted to urban areas. Septic tank sludge is, however, included in the rules, but there are no specifications for faecal sludge.

Given the absence of appropriate legislation of any monitoring mechanism, faecal sludge management has remained severely deficient and outdated. It is currently an unauthorized sector and works in highly adverse and unhygienic conditions. After collection from households by private vehicles, faecal sludge is disposed of in open areas, waterbodies or forest areas, thus generating serious health problems and environmental degradation. Unless techno-economically viable alternatives are developed, sewage sludge management will be a formidable task in environmental management.

5.2 USING TREATED FAECAL SLUDGE

Public health is the most important concern in reusing faecal sludge as quality issues linked with the safety of faecal sludge reuse remain unclear. The difficulty in delineating acceptable health risks of reusing treated faecal sludge is an ongoing debate all over the world.

It is traditionally suggested that faecal sludge can be applied on and as a soil conditioner and as a fertilizer. However there are concerns with regard to its handling, transportation and odour as open disposal of sludge poses a threat to public health and environment. However, studies suggest that the raw faecal sludge can be effectively utilized for the production of biofuels. A study by Sultan Qaboos

University (Oman) validates that faecal sludge makes excellent feedstock for bioethanol and biodiesel production and yields more biomethane when compared to that produced from cow faecal waste.[20]

After adequate treatment, faecal sludge should be analysed for physiochemical and biological parameters. For sample collection, the following measures and precautions should be observed: samples shall not be taken at a place exposed to rain or sun; the contents should be mixed as thoroughly as possible by suitable means to draw a representative sample; and the sample should be kept in a suitable, clean, dry and airtight glass, a tightly closed polythene bottle of about 400 gm capacity, or in a thick-gauged polythene bag.

Box 17: Countrywide initiative of using sludge as a resource in Bangkok

Bangkok, Thailand, is a large metropolitan area with a population expected to reach 7 million by 2030. The city's high rates of urbanization make tackling the challenge of pollution necessary.

In Thailand's agriculture-based economy, sludge is perceived as a valuable resource. It is well recognized by farmers, businesses, government and local researchers and is collected, treated and transformed to be sold for reuse as fertilizer. More than 60 per cent of the population engages in agriculture, and agricultural exports account for more than 60 per cent of total exports. Bangkok, though very urbanized, has kept a strong agricultural sector, with a total agricultural area of 21,000 km^2, representing about 14 per cent of the total area of Bangkok Metropolitan region.

Sludge reuse activities are shaped by two main national programmes, the National Economic and Social Development (five-year plans) and the National Sewerage Development 32 Year Plan (2010-2041). The Office of Natural Resources and Environmental Policy and Planning (ONEP) establishes the environmental policy and programmes and checks the priority of sewerage projects at the national level.

The strategy of the Bangkok Metropolitan Administration (BMA) is to collect and treat septic sludge to be used as fertilizer in the city's public parks, surrounding green areas and farmland. It also aims to produce compost with a mix of natural rice straw and dewatered sludge from the 12 wastewater treatment plants to be used as manure. Both the use of treated sludge and composted sludge grow to balance out the increase in wastewater treatment coverage and respond to a local demand in fertilizers. Assuming the current usage, it is estimated that the production capacity of the composting plant will be increased to meet the annual demand of fertilizers (estimated at 12,000 m^3) by 2030.

Source: https://www.iwa-network.org/wp-content/uploads/2018/02/OFID-Wastewater-report-2018.pdf

After the analysis is conducted, the following end-uses can be suggested: use of sludge as boiler fuel (briquette of faecal sludge), and use as organic fertilizer, composting or vermicompost, and soil conditioner. The most promising application is the use of treated faecal sludge as a fertilizer.

Although there are no specifications and guidelines from the Indian government for the use of treated faecal sludge as an organic fertilizer, the specifications of the Fertilizer (Control) Order, 1985 can be used as the guiding document (*see Table 23: Specifications for organic fertilizers*). City compost is prepared from biodegradable municipal solid waste by using the conventional composting method (windrow) while vermicomposting involves use of earthwork to facilitate composting production.

Soil conditions that have deteriorated because of the long-term use of chemical fertilizers can be improved by the use of treated faecal sludge. The faecal sludge-based compost can effectively support plant vegetation by providing abundant nutrients, soil organic matter, appropriate pH and high water-holding capacity. Faecal sludge has a pH-buffering capacity resulting from alkalinity, which is beneficial to reclaiming acidic soil and makes it humic.

In South Africa's eThekwini municipality (Durban city), the LaDePa—or Latrine Dehydration Pasteurization—machine was used to popularize the use of decomposed faecal matter in agriculture. The machine helps treat faecal sludge collected from single-pit toilets. The faecal sludge is extruded for the formation of pellets, which are then exposed to infrared radiation. The final product is dried and pasteurized pellets that become safe to handle, with minimum risk of exposure to pathogens and readily available for agricultural usage.

Table 23: Specifications for organic fertilizers (FCO 1985)

	City compost and vermicompost
Moisture	15–25
Colour	Dark brown to black
Odour	Absence of foul odour
Particle size	Minimum 90 per cent material should pass through 4 mm IS sieve
Bulk density	< 1
Total organic carbon (per cent by weight; minimum)	12
Total nitrogen (as N) per cent by weight; minimum)	0.8
Total phosphates (as P_2O_5) per cent by weight; minimum)	0.4
Total potash (as K_2O) per cent by weight; minimum)	0.4
C:N ratio	< 20
pH	6.5–7.5
Conductivity	4.0
Pathogens (faecal coliform, salmonella and E coli)	Nil
Heavy metal content (as mg/kg), maximum limit	
Arsenic (as As_2O_3)	10
Cadmium (as Cd)	5
Chromium (as Cr)	50
Copper (as Cu)	300
Mercury (as Hg)	0.15
Nickel (as Ni)	50
Lead (as Pb)	100
Zinc (as Zn)	1000

Source: http://krishi.bih.nic.in/Acts-Rules/Fert_Order_1985.pdf

Box 18: Use of treated faecal sludge in Ghana—perception matters

A study to evaluate the perception of farmers using treated faecal sludge as an organic fertilizer was performed in peri-urban areas of Ghana. The key objectives were to investigate farming practices and types of fertilizer farmers used, assess farmers' knowledge on the use of faecal sludge compost, and explore sociocultural and health issues relating to faecal sludge compost.

A total of 150 farmers from three communities were selected in two districts of the Ashanti region (in Ghana) using a random sampling method. Data was collected from each farmer through semi-structured questionnaires. All the farmers surveyed applied some form of organic or inorganic fertilizer on their farms. The results of the study showed that 28 and 51 per cent of farmers used organic and inorganic fertilizers respectively, while 21 per cent of the farmers used both organic and inorganic fertilizers. Only 34 per cent of the farmers were aware that faecal sludge is a useful source of fertilizer, and only 4 per cent used it to fertilize their farms.

Health risks associated with the use of faecal sludge as compost were not the main reason why most of the respondents had a negative attitude towards the use of faecal sludge compost. Instead, faecal sludge was considered a waste product that must not be used. The study also highlighted that the farmers who applied faecal sludge compost as organic fertilizer had increased crop yields while reducing the sanitation problem caused by the indiscriminate disposal of faecal sludge into the environment.

Source: Appiah-Effah, E. et al., 2015. Perception of Peri-Urban Farmers on Fecal Sludge Compost and Its Utilization: A Case Study of Three Peri-Urban Communities in Ashanti Region of Ghana. Compost Science and Utilization 23, 4.

Chapter 6: SUGGESTED POLICIES AND STRATEGIES FOR SUSTAINABLE MANAGEMENT OF FAECAL SLUDGE AND WASTEWATER

KEY POINTS

- The wastewater and faecal sludge management sector faces problems due to lack of regulation, lack of investment and lack of appropriate knowledge about suitable technologies and lack of communication strategies.
- Capacity-building and awareness activities for users, government bodies and private players should be undertaken not only on the available technologies for treatment of excreta but also on emptying of pits and septic tanks, collection of sludge, transportation, treatment and disposal of both faecal sludge and wastewater.
- CSOs/NGOs, communities and artisans should also be aware of the safety standards of the treated sludge and wastewater before they use them in their fields or for any other purpose.
- The District Panchayat should train service providers emptying the sludge on safety norms (during collection and transportation of sludge), vehicle design, desludging process, safety gears and safe transportation to the treatment facilities.
- This chapter proposes a legal framework for containment and transportation of untreated sludge to treatment plants.
- It discusses the steps towards changing behaviour with regard to safe sanitation, specifically faecal sludge management and its reuse options.
- The roles and responsibilities of the stakeholders have been described in the proposed communication strategies.

There is a need to understand that moving towards an open-defecation free state does not mean building any type of toilets. The whole process of the sanitation chain from safe containment to reuse options for decomposed excreta should be considered. Managing excreta cannot stop at building any kind of pit or septic tank. Sludge should also be emptied from pits and septic tanks—with technical guidance followed—and undigested sludge should be transported to treatment plants. Reuse or safe disposal options should also be available.

The challenges in the wastewater (grey and black) and faecal sludge management sector include: (i) lack of proper regulation, (ii) lack of investment in infrastructure, (iii) use of efficient technologies, and (iv) lack of monitoring and communication strategies.

India has not done much in the sector of faecal sludge and grey- and black-water management in rural areas; the new phase of SBM (2.0) will focus on this. The main hindrance may be the low capacities of stakeholders in this sector. Capacity-building and awareness activities should be undertaken for users, government bodies and private players not only on the available technologies for the treatment of excreta but also on emptying pits and septic tanks, collection of sludge, transportation, treatment and disposal of both faecal sludge and wastewater (grey and black water). Educating both government representatives and private players about designs of septic tanks and dual pits/ventilated improved pits should be part of capacity building programmes. It is also important to make the CSO/NGOs, communities, self-help groups and artisans aware about the safety standards under the Information Education Communication activities. District panchayats should train service providers on safety norms (during collection and transportation of sludge), vehicle design, desludging process, safety gears and safe transportation to treatment facilities. State and Panchayati Raj Institution (PRI) officials should be trained in implementation of model projects on decentralized grey- and black-water management. Faecal sludge management, treatment and various reuse options (of treated sludge) components should be integrated in ongoing capacity-building programmes. At the state level, fiscal policies and budgeting should address the specific needs of women, adolescent girls and transgenders.

6.1 LEGAL PROVISIONS FOR ON-SITE CONTAINMENT AND TRANSPORTATION OF FAECAL SLUDGE

This section details how to set up a regulations guideline framework for on-site containment and transportation of faecal sludge. The following points are defined:

- Each step of the sanitation value chain—the design, operation and maintenance of the system—should be well defined,
- Insanitary toilets should be retrofitted or converted to sanitary ones,
- Incentives should be given to communities for retrofitting,
- Licences should be issued to private service providers, and
- Incentives should be provided to sanitation services, and penalties for violation of rules for service providers.

A. Who will be responsible? The district panchayat shall be in charge of defining the roles and responsibilities of stakeholders, developing the institutional framework and enforcing the by-law of faecal sludge (and wastewater) management systems.

B. Applicability of the regulation: The regulation has been designed for rural and small towns, both classified as rural by the Department of Drinking Water and Sanitation (DDWS) focussing on on-site sanitation only.

C. Activities proposed under this regulation:

- *Retrofitting or conversion of insanitary toilets to sanitary toilets*: The Management Information System (MIS) of the Department of Drinking Water and Sanitation (DDWS) gives a database of toilets built at the household and community levels. It specifies whether safe technologies have been followed for improved sanitation. A database of toilets built improperly—those that did not follow safe norms or failed to take into consideration of soil strength and/or type and hydrogeological condition—should also be developed. All existing toilets have already been geo-tagged; adding information about their functionality and faecal sludge management will be helpful. Households should be informed about insanitary conditions. Incentives in the form of discounts on tariffs on water or any other services provided to the community (or households) shall be provided for such retrofitting. Communities, households and neighbourhoods should be made aware of the regular schedule of removing the sludge from pits and septic tanks. As toilets are linked to the Geographic Information System (GIS), regular monitoring of desludging as per schedule can be added to the parameters.

- *Emptying and collection of faecal sludge*: Pit toilets or the septic tanks need to be desludged by household owners and private desludgers. Twin-pit toilets or ventilated improved pit toilets should have honeycomb brick walls for degradation of sludge and absorption of liquid (as per the design given in Chapter 2); as one pit fills up, faecal sludge decomposes in the other pit. The decomposed sludge in these cases can be emptied by household owners or toilet-owner associations. All existing septic tanks should have access covers for each chamber so that they can be easily opened during the emptying process. Where such covers are not available, it should be made compulsory for all property owners to provide proper covers. The new septic tanks need to be designed and constructed as per the suggestions in Chapter 2.

  When private desludgers are engaged, they shall apply for licence from the district panchayat. The term of the license should be for a maximum of five years. The database of licensed desludgers should be made available to communities through ministry portals, newspapers and even local advertisements. After desludging, the operator shall ensure the cleanliness of the area. Any leaks must be disinfected with a bleach solution or by spreading lime over the spillage. It is the collection operator's responsibility to verify that sufficient disinfectant (bleach or lime) is on the truck prior to dispatching it for service.

Desludging workers must wear appropriate personal protective equipment.[21,22] This includes rubber gloves, rubber boots, a face mask and eye protection. After pumping activities, operators should wash their hands with soap. Collection should preferably be done when traffic in the area is light. All collection vehicles shall have early warning devices and traffic cones should be placed at the back and front of the vehicle during operation.

It is the responsibility of the collection operator to check the truck's safety equipment daily prior to dispatching the unit for service. Any safety equipment deficiencies shall be reported to the supervisor and repaired before dispatch. The community shall directly upload the feedback of the private operator on the web portal of the local government authority. The service provider must maintain records about households served and land application as per the local ordinance. Based on the feedback of the community, the service provider will be allotted future contracts. In cases of malpractice, the district authority shall cancel the licence.

Box 19: Best practice: How a local government interacts with the community in desludging

The city authority of Marikina, in the Philippines, in a joint venture with the water utility, has set up an organized desludging programme. The government agency has partnered with private service providers for the following operations:

- A few days before the service providers are in the neighbourhood, they send out a truck with a loudspeaker to advise residents of the pending service;
- The day before sludge removal takes place, city workers visit the homes and pass around informational brochures;
- They identify the households that require the service and provide them with a list of service providers who will provide their service at economic rates;
- On the day of emptying of the sludge, the government agency is present to troubleshoot.

The outcome is 95 per cent compliant with sludge removal requirements as per the local ordinance and must have vehicles for transportation.

Source: Sunita Narain, Sushmita Sengupta, Rashmi Verma and Heli Shah, 2019, Nigeria: Improving the State of Sanitation, Centre for Science and Environment, New Delhi

➢ *Transportation of faecal sludge:* The traffic police shall keep a track of whether desludgers are plying with a valid license. The operators identified by the government agency must have vehicles for transportation that meet the standards of the local ordinance. The workers shall be trained enough to handle the waste. To avoid any leak or spill from the vehicles during transportation, all the inlets and outlets should be constructed with leak-proof materials and maintained regularly; to avoid flooding and spraying at the receiving area, the discharge outlets should be designed accordingly. The vehicle shall be painted to clearly mark for public information that it is carrying untreated sewage. To monitor the movement of trucks, they should be tracked through GPS tracking system.[23] In the event of accidental spillage of sludge, the operator shall immediately take action to contain the sludge, minimize its environmental impact, and begin clean-up procedures. The operator shall notify concerned officials about the spillage and the nature of remedial action within 24 hours. Penalties may be imposed on the operators who do not comply with the guidelines.[24]

➢ Issuing licence for collection and transportation of faecal sludge:

Every service vehicle applying for the licence needs to comply with the following[25, 26]

- The applicant shall display the company name, company logo, contact number and business registration number of the transporting vehicle on both sides;

- The applicant shall display the service area and final point where the sludge will be transported;
- The applicant shall have vehicles which have leak proof body and strong locking mechanism to withstand collision with heavy and strong vehicles and structures; and
- The workers should be well trained and must wear appropriate personal protective equipment (PPE).

Once the licence is received, a copy of the license should be displayed on the transport vehicle.

6.2 COMMUNICATION STRATEGIES

While preparing the communication strategy for awareness on faecal sludge management in rural areas, a comprehensive evidence-based strategy has to be developed so that it can be easily adopted by the policymakers and implementers of the strategy. The communication strategies targets to change the behaviour of the household owners, members of village water and sanitation committees/pani panchayat, contractors, masons and plumbers, panchayat officials (village, block and district) and industries.

The strategy should address the creation of the following objectives:

➢ 'Sanitation' should not be restricted to toilets: Series of campaigns have to be planned so that the idea that sanitation is not limited only to water closets but to the full cycle of excreta management.

➢ The responsibility of household owners should be redefined: There is a need to increase the sense of responsibility of household owners and panchayats and to focus on larger sanitation outcomes in their neighbourhoods, villages and even districts.

➢ Managing faecal sludge and the wastewater should be the new mantra: It is essential that the village water and sanitation committee/pani panchayat take up the full cycle of sanitation, including the treatment of sludge and its reuse. The decentralized treatment of wastewater should be another major focus for the community. The district panchayats should regulate and enforce the rules to manage faecal sludge following the Panchayati Raj laws.

To reach these objectives, behaviour change communication should have two kinds of approaches: [27]

- An umbrella approach: Campaigns based on this approach will address the broad overarching issues of bringing in public consciousness the treatment and reuse of faecal sludge;
- A specific approach: Campaigns based on this approach are smaller ones under the umbrella campaign. For example, a behavioural change campaign launched targeting household owners, members of village water and sanitation committees/pani panchayat, contractors, masons and plumbers, panchayat officials and other decision makers on the regulations to manage the faecal sludge and the consequences of non-compliance of these rules.

Rather than only producing pamphlets, hoardings and adverts, the focus of such strategies will effectively change existing behaviour or bring in new habits and persistent awareness programmes. This strategy will:

- Target the population that is willing to change first and then the rest,
- Frequently talk about the benefit of the new behaviour and highlight the drawbacks of the old behaviour, and
- Not refer to doing away with old practices.[28]

➢ Panchayat officials (village, block and district)/village water and sanitation committee/pani panchayat

Objective: To make faecal sludge management (or safe sanitation) the priority in the district/block/panchayat/village

Efforts: Factsheet, FAQs, multimedia presentations on safe sanitation; meetings in local language, workshops to spread the knowledge on technologies, financial options for safe sanitation; personalized communications by celebrities and ministers to sensitize the population about the benefits of faecal sludge management

- Households

  Objective: To make household owners aware about the issues around unsafe sanitation, e.g. faulty toilets, dumping untreated sludge in the waterbodies, drains and farms

  Efforts: Talk shows on radio and television; jingles; including the topic of safe sanitation in serials and radio shows

- Media

  Objective: To increase coverage on safe sanitation

  Efforts: Factsheets, FAQs on safe sanitation, meetings with journalists and editors to make them aware about safe sanitation. Exposure to success stories and fellowships offerred to cover stories on the subject

- Industries/corporate

  Objective: To involve the corporate sector in the sanitation campaign

  Efforts: Meetings and special events to raise awareness on safe sanitation, especially among corporates interested in funding safe sanitation. Briefing workshops with industries who can use treated faecal sludge

- Masons and plumbers

  Objective: To improve their capacities in safe sanitation technologies

  Efforts: Factsheet, FAQs, multimedia presentations on safe sanitation, meetings in the local language, workshops on technologies

The output of such strategies will be as follows:

- Households use their own toilets and ultimately stop going out for defecation,
- Child faeces is disposed of in toilets,
- Every household starts using 'sanitary toilets' following design specifications,
- Faulty toilets are retrofitted,
- Reduction in contamination of water and soil,
- Reduction in expenditure on health-related issues,
- Household owners voluntarily make arrangements to clean pits and septic tanks as per the schedule fixed by the village water and sanitation committee/pani panchayat,
- Household owners ensure that the collected sludge is treated to safe limits before being disposed of or reused as fertilizers, and
- Gram panchayat makes the faecal sludge management the new mantra.

Chapter 7: CONNECTING WATER TO TOILETS

KEY POINTS

- This chapter tells us that only constructing toilets with correct technology will not ensure toilet usage.
- It takes us through the importance of water connectivity to make toilets functional.
- Supplying water at the rate of 55 litres per capita per day (lpcd) for rural households is essential adequate water for toilet usage and maintenance. Currently, around 47 per cent of the population is covered by 55 lpcd; this is not enough water to keep all the toilets functional.
- Around 0.0084 million hectares of land has rainwater harvesting potential of 50,490,000 billion litres, which is enough to supply water to a population of 918 million at a rate of 55 lpcd even with a collection efficiency of 50 per cent.
- This chapter proposes policies to promote decentralized water projects, including protection of waterbodies, to be planned and implemented by the community. Inclusion of women is important in such projects. The proposed policies include incentives and awards for communities involved in such projects.

As is seen from a Comptroller and Audit General (CAG) report, the construction of toilets is critical to ending the scourge of open defecation.[29] CSE researchers travelled to different states to find that people were not using toilets as toilets had no water available. This is seen in Rajasthan, Gujarat and Uttar Pradesh. For example, Jhansi in Uttar Pradesh, which seemed to have solved its problem of open defecation, failed to sustain it during peak summers. To make such toilets functional, they must have continuous water supply.

According the Management Information System (MIS) provided by the Department of Drinking Water and Sanitation (DDWS), only 19.85 per cent of rural households are connected to water (data as on 23 February 2020). Since the DDWS talks about 'Har Ghar Jal', we assume that piped-water supply means water at the doorstep of each household and not 'within the household premises or at a distance of not more than 100 metres from their households' as was DDWS's earlier undertaking.

According to the same MIS, in April 2019 around 54 per cent of population were connected to piped-water supply, which when compared to household connections during the same time is only 18.3 per cent.

Table 24: Coverage with respect to 40 lpcd far more than with respect to 55 lpcd

Year	Fully covered by 40 lpcd	Fully covered by 55 lpcd	Coverage with respect 40 lpcd	Coverage with respect 55 lpcd
Apr 2019	1,396,498	815,663	80.9	47.3
Apr 2018	1,361,006	805,775	78.9	46.7
Apr 2017	1,325,302	765,833	76.8	44.4

Source: DDWS

According to the CAG report, which analysed the state of rural water supply between 2012 and 2017, 4.76 lakh habitations slipped from the fully covered to the partially covered state. The number of slip-back habitations was high in Andhra Pradesh, Bihar, Karnataka, Jharkhand, Odisha, Rajasthan, Uttarakhand and West Bengal. It was seen that so far almost 8.5 lakh schemes for piped-water supply came from groundwater, which was almost seven times those from surface water source. In February 2014, the then minister of Drinking Water and Sanitation, Shri Bharat Singh Solanki, informed the Lok Sabha in reply to a question that the norm to provide water supply in rural areas was fixed at 55 litres per capita per day (lpcd) for humans to meet the requirements for drinking, cooking, bathing, washing utensils and ablutions, based on the basic minimum need during the 12th Five-Year Plan. But the current MIS tells that there are habitations which still receive 40 lpcd of water. As per February 2020, only 47 per cent of habitations have 100 per cent coverage with 55 lpcd which do not necessarily mean that their households have taps for water (*see Table 24: Coverage with respect to 40 lpcd far more than with respect to 55 lpcd)*

Under the 55 lpcd norm, the demand for cleaning and toilet usage will be challenged, assuming that 10 lpcd of water is used for ablutions or toilets and an additional 15 lpcd is allotted for washing. The fact of the matter is that if a person uses a pour-flush toilet, the water can support a maximum of two visits per person but there is no water to maintain the toilet everyday. Hence if the toilets need to be useable, people should not only be supplied piped water at the household level but also at 55 lpcd (*see Table 25: Household water-supply norms*)

Table 25: Household water-supply norms

Purpose	Quantity (lpcd)	
	40 lpcd norm	55 lpcd norm
Drinking	3	3
Cooking	5	5
Bathing	15	15
Washing utensils and house	7	10
Ablution	10	10
Washing of clothes and other uses	–	12
Total	**40**	**55**

Source: DDWS and CAG report

To maintain its open-defecation free status, the government has the massive job of providing water to all the toilets built. There is a gap in understanding that water and toilets are correlated. Unless there is equal expenditure on resources for development of both sanitation as well as water availability, people will abstain from using toilets on a regular basis. Hence initiatives should be taken to construct toilets which are less water intensive, especially for the population in poorest quintile. Since a large part of the population depends on borewells or tube wells, a scheme for rainwater harvesting should be prioritized in the country.

Box 20: Potential of water harvesting to meet India's rural household water needs

Assumptions

Rural population = 918 million[30]

Average annual rainfall = 1183 mm[31]

Land area for which land-use records are available: 304 million hectares

Average household requirement in rural households = 55 litres/day/person

Annual water requirement in a year for a population of 918 million at the rate of 55 litres per capita per day = 50,490,000 billion litres

Land requirement = 0.0084 million hectares (assuming that the collection efficiency is just 50 per cent)

Source: Agarwal, A, Narain, S. 1997. Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems (State of India's Environment, Volume 4). Centre for Science and Environment. p. 29.

Proposed steps for the country:

- National policies should be worked out to encourage the growth of small water-harvesting systems. The systems should be planned and managed by the community.
- Traditional systems of harvesting systems should be revived. A healthy mix of traditional and modern systems should be used but priorities should be given to traditional systems as they conserve rainwater.
- Lakes and waterbodies should be protected and created while degraded ones should be revived by the communities with minimal involvement of the states. Emphasis should not be on community participation but on community governance. This implies not just social management of water-harvesting structures handed over by states but also involvement of communities in both planning and implementation.
- Women should also be equally included in the planning, design and implementation of such projects. This is because women and adolescent girls are worst affected by water scarcity and they play an important role in carrying water from distant places.
- Major investments have to be made to increase the capacity of communities so that they efficiently operate and maintain the rainwater harvesting structures (including lakes and waterbodies) in different ecological regions.
- Finances for the initial construction and rehabilitation of the water harvesting structures should come from the community as much as possible. At least 25–30 per cent can be obtained from the community, provided the investment planning for rehabilitation is undertaken by the community itself, with state agencies and other external agencies playing only a supportive role. The exact modalities of financing and cost recovery should be left to the community. The community must contribute effectively at all stages of the project. While state subsidies may be necessary, their level should be decided according to the community needs and regional specificities. Furthermore, greater emphasis has to be on subsidies to the community rather than on private subsidies to individuals.
- State Rural Department of Water and Sanitation should incentivize, with awards and discounts in water tariffs, communities that undertake source sustainability projects for water supply through rainwater harvesting.
- Jal Jeevan Mission says that once a rural area is declared open-defecation free, it should have a steady source of water to their toilets for regular usage (if flush or pour-flush toilets), self and hand washing purposes. The Mission should involve communities in planning and implementation of decentralized water supply projects for this purpose.

FAQs

1. What is sanitation?

Sanitation refers to the provision of facilities and services for the safe management of human excreta. It ensures health and well-being of the people. According to the United Nations Department of Economics and Social Affairs (UNDESA), basic sanitation refers to the facilities that ensure hygienic separation of human excreta from human contact. Improper sanitation causes illness like diarrhoea, malaria, schistosomiasis and trachoma, to name a few. Sanitation is essential for health, preventing environment pollution and conserving ecosystem. Sanitation can create a business around recovering and recycling resources from excreta

2. What is sanitation value chain?

Sanitation value chain is a sequence of processes that starts with the collection of untreated or semi-treated faecal waste and ends with the treatment and reuse of this waste as a resource such as organic manure, energy or even water (for non-potable uses). As the first step, the value chain ensures that faecal waste is safely collected and the community and environment do not come in contact with this waste. Such a value chain is applicable when communities use single-pit or septic tanks. Thus the full cycle of sanitation includes five stages, namely, 1) safe containment (coomprising toilets and septic tanks or drainage systems), 2) safe-emptying services such as desludging, 3) safe transport of waste by trucks, 4) safe treatment in sewage treatment plants or faecal sludge treatment plants, and 5) safe disposal/reuse. In areas where twin pits can effectively treat faecal matter on the site itself, the sludge is converted to compost within the pits and can be used directly by the farmers.

3. What does containment mean?

Containment is a stage where the human waste is collected through toilets and stored in a containment structure like a septic tank or a twin pit.

4. What is wastewater?

Wastewater is the water released to drains or open spaces after the domestic, industrial or commercial usage. By composition, wastewater is mostly water by weight. Other materials make up only a small portion of wastewater; this includes organic matter, microorganisms and inorganic compounds. This change in chemical properties of water can harm public health and the environment.

5. What do you mean by aerobic and anaerobic way of treatment of wastewater?

Anaerobic and aerobic systems are types of biological treatment that require microorganisms for remediating wastewater. Both processes involve the breakdown and decomposition of contaminants from wastewater. The key difference between anaerobic and aerobic treatment is that aerobic systems work in the presence of microorganisms that require oxygen for growth, while anaerobic systems work in presence of microorganisms that do not require oxygen for their growth.

6. What is the difference between black and grey water?

Black water is wastewater coming out of the toilets, and grey water is the wastewater generated due to any domestic water use, excluding that coming out of toilets. The key difference between the two is that black water comes into contact with faecal matter and contains harmful bacteria and disease-causing pathogens. Grey water, on the other hand, does not come in contact with solid human waste. This greatly decreases the risk of disease caused due to the disposal of grey water into the environment. Both black and gray water contain pollutants and disease-causing agents that require treatment before further reuse or disposal into the environment.

7. How is sewage different from faecal sludge?

Sewage is untreated wastewater that contains faeces and urine. This wastewater is generally conveyed through the sewerage system from homes to sewage treatment plants. Grey water from kitchens and bathrooms also becomes part of sewage. Faecal sludge on other hand is the solid or settled contents of pit latrines and septic tanks. It is raw or partially digested slurry or in a semi-solid form and results from the collection, storage or treatment of combinations of excreta and black water, with or without grey water.

8. What is deep-row entrenchment? Is it safe?

Deep-row entrenchment is a technology that can be considered as both a treatment facility and end-use option. It encompasses digging of deep trenches on the land, filling the trenches with sludge and covering them with soil. Trees are planted on the top of the soil; green plants get organic matter and nutrients from sludge buried in the soil. This leads to more trees growing. The technology is simple and economical; it has low O&M. The land requirement is very high. This technology is not advisable in areas that have a shallow groundwater.

9. What is leachate?

Leachate can be defined as contaminated liquid which is produced from water percolating through a heap of solid waste or accumulated containments. Leachates can also be produced if moisture content of certain disposal sites is released though any kind of compaction or chemical reaction. This contaminated liquid can move to the subsurface soil and contaminate the soil and groundwater.

10. What is a vacuum tanker?

A vehicle used to extract faecal sludge from septic tank is a vacuum tanker. It is connected to a pump and water jetting systems. The vehicle carries the sludge to a treatment site. The vehicles are also called honey suckers.

11. What is a pour-flush toilet?

A pour flush toilet is like a regular flush toilet except that instead of water coming from a cistern above, it is poured in by the user. Like in a traditional flush toilet, there is a water seal that prevents odours and flies from coming back up the pipe. In rural areas of India, it is advisable to use pour-flush toilets as they use only 2–3 litres of water per flush. But they should be complemented with specially designed toilet pans (at an acute angle of 25–29 degree) which also help in washing away of the excreta in an easy way.

12. What is a sanitary toilet?

A sanitary toilet is a toilet connected to a containment, which does not allow the excreta to leak into the environment.

13. What is an insanitary toilet?

Insanitary toilet is a toilet connected to any unsafe containment structure that causes the excreta to leak out into the environment.

14. What is a ventilated improved pit (VIP) toilet?

A VIP toilet is an upgraded single-pit toilet, where the pit is connected to a vent pipe with fly-proof netting on top of the pipe. The ventilation keeps the toilet free from odours and flies. The superstructure includes an aerated room and a squatting hole for excreta to directly fall into the pit.

15. What is a community toilet?

Toilets located in a common or a central place where a families living within the community can use them are called community toilets.

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The Swachh Bharat Mission (SBM)—launched in 2014— saw the construction of more than 164 lakh household toilets in over 6 lakh Indian villages. The Department of Drinking Water and Sanitation, under the Ministry of Jal Shakti—which looks after water and sanitation facilities in rural areas—will now focus on SBM 2.0, which deals with safe management of faecal sludge. SBM 2.0 follows Phase I of SBM (Grameen), which was concerned solely with access to toilets.

On-site sanitation systems are the only way to treat black water from toilets in rural areas. Toilet technologies should hence be chosen carefully, in consonance with the geography and the hydrogeology of a terrain.

This toolkit describes the best technologies to treat excreta in accordance with site conditions. It takes us through the processes to treat untreated or partially treated sludge extracted from on-site sanitation systems. It focuses on safe disposal and reuse of treated faecal sludge as well as aspiring business models around reuse options. Technologies used for faecal sludge management in rural areas are illustrated through case studies from the around the world. The toolkit also proposes a legislative framework for by-laws on faecal sludge management and policy guidelines to ensure water supply in every toilet.

Centre for Science and Environment
41, Tughlakabad Institutional Area,
New Delhi 110 062 Phones: 91-11-40616000
Fax: 91-11-29955879 E-mail: cse@cseindia.org
Website: www.cseindia.org