Report Code: 039_GBP_IIT_EQP_DAT_01_Ver 1_Dec 2013

Sanitation in India

A Review of Current Scenario

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology







IIT Bombay | **IIT Delhi** | **IIT Guwahati** | **IIT Kanpur** | **IIT Kharagpur** | **IIT Madras** | **IIT Roorkee**

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

Dr Vinod Tare
Professor and Coordinator
Development of GRBMP
IIT Kanpur

The Team

1. A A Kazmi, IIT Roorkee *kazmifce@iitr.ernet.in*
2. A K Gupta, IIT Kharagpur *akgupta18@rediffmail.com,akgupta@iitkgp.ac.in*
3. A K Mittal, IIT Delhi *akmittal@civil.iitd.ernet.in*
4. A K Nema, IIT Delhi *aknema@gmail.com*
5. Ajay Kalmhad, IIT Guwahati *kajay@iitg.ernet.in*
6. Anirban Gupta, BESU Shibpur *guptaanirban@hotmail.com*
7. Arun Kumar, IIT Delhi *arunku@civil.iitd.ac.in*
8. G J Chakrapani, IIT Roorkkee *gjcurfes@iitr.ernet.in*
9. Gazala Habib, IIT Delhi *gazalahabib@gmail.com*
10. Himanshu Joshi, IIT Roorkee *himanshujoshi58@gmail.com*
11. Indu Mehrotra, IIT Roorkee *indumfce@iitr.ernet.in*
12. Ligy Philip, IIT Madras *ligy@iitm.ac.in*
13. M M Ghangrekar, IIT Kharagpur *ghangrekar@civil.iitkgp.ernet.in*
14. Mukesh Doble, IIT Bombay *mukeshd@iitm.ac.in*
15. P K Singh, IT BHU *dr_pksingh1@rediffmail.com*
16. Purnendu Bose, IIT Kanpur *pbose@iitk.ac.in*
17. R Ravi Krishna, IIT Madras *rrk@iitm.ac.in*
18. Rakesh Kumar, NEERI Nagpur *r_kumar@neeri.res.in*
19. S M Shivnagendra, IIT Madras *snagendra@iitm.ac.in*
20. Saumyen Guha, IIT Kanpur *sguha@iitk.ac.in*
21. Shyam R Asolekar, IIT Bombay *asolekar@iitb.ac.in*
22. Sudha Goel, IIT Kharagpur *sudhagoel@civil.iitkgp.ernet.in*
23. Suparna Mukherjee, IIT Bombay *mitras@iitb.ac.in*
24. T R Sreekrishanan, IIT Delhi *sree@dbeb.iitd.ac.in*
25. Vinod Tare, IIT Kanpur *vinod@iitk.ac.in*
26. Vivek Kumar, IIT Roorkee *vivekfpt@iitr.ernet.in*

Lead Persons

1. Vinod Tare *vinod@iitk.ac.in*
2. Purnendu Bose *pbose@iitk.ac.in*

There is considerable awareness about community water supply needs, but the problems of excreta and sewage disposal, i.e., sanitation, has received less attention in India. The effects of poor sanitation seep into every aspect of human life be it health, welfare, economy, dignity, empowerment or environment.

To meet the country's sanitation challenge there is an urgent need to focus on proper collection and treatment of excreta and sewage and to build and maintain appropriate toilets for all. Government has spent and is still spending a lot of money to improve the state of sanitation, but majority of systems have failed due to various reasons.

In this report the currently available sanitation solutions have been critically assessed and analyzed to determine their relative merits and demerits, especially with regard to Indian conditions and sensibilities. The minimum requirements of an effective sanitation system have also been identified.

Dr Purnendu Bose
IIT Kanpur

Contents

1. Introduction

Sanitation is the most neglected sector in India. The general tendency is to just transport the waste out of sight; nobody is concerned about the fate of that waste, believing that that nature will automatically take care. But unfortunately that's not true; the effects of poor sanitation seep into every aspect of human life.

In India only 30% of urban households have access to sewer lines, while this percentage is almost zero in rural areas. Growing volumes of untreated sewage contaminate ground water and surface water. Rivers and drainage channels are carrying raw sewage. A large portion of the population has no access to toilets. These people cannot defecate in privacy and are forced to go out to defecate in open fields, near rivers or on railway tracks. To meet the country's sanitation challenge there is an urgent need to focus on building appropriate toilets, ensuring their quality, use and maintenance and further treat the waste from these toilets properly before disposal.

In the last few years, substantial funds have been spent by both central and state governments on building of the sanitation infrastructure in the country. However due to a variety of reasons including inappropriate sanitation solutions adopted, the results from such initiatives have been less than heartening, Even now, an unacceptably large percentage of Indian population have no access to toilets and hence practice open defecation.

There is an obvious need for good sanitation systems, which are complete in themselves, i.e. these systems should not compromise at any end. Therefore such systems must have certain important properties,

- **Disease prevention:** A sanitation system must be capable of destroying or isolating pathogens.
- **Environment protection:** A sanitation system must prevent pollution and conserve valuable water resources.
- **Nutrient recycling:** A sanitation system should return nutrients to the soil.
- **Affordability:** A sanitation system must be accessible to the poorest people.
- **Acceptability:** A sanitation system must be aesthetically inoffensive and consistent with cultural and social values.
- **Simplicity:** A sanitation system must be robust enough to be easily maintained with the limitations of the local technical capacity, institutional framework and economic resources.

Since a large number of sanitation options are currently available, it is important to do a critical evaluation of these in order to identify optimal solutions for a given scenario. In subsequent sections of this report, the currently available sanitation solutions have been analyzed to determine their relative merits and demerits, especially with regard to Indian

conditions and sensibilities. The minimum requirements of an effective sanitation system have also been identified.

2. Sanitation

A WHO Study Group in 1986 formally defined 'sanitation' as "the means of collecting and disposing of excreta and community liquid wastes in a hygienic way so as not to endanger the health of individuals and the community as a whole". Safe disposal of excreta is of utmost importance for health and welfare of society and also for the social and environmental effects it may cause to the communities involved.

Ownership of a toilet does not always lead to better adoption of sanitation and hygiene practices. Often error in design, improper or no maintenance, lack of knowledge of proper usage of toilet and insufficient running water in the vicinity are the causes of dissatisfaction amongst users, resulting in a return to open defecation. Open defecation is practiced in India more than anywhere in the world (more than 600 million individuals) [1].

Most of the sanitation systems prevalent today are either based on storing human excreta in pits ('drop-and-store') or on flushing it away with water ('flush-and discharge'). Drop-and-store systems can be simple and relatively economical but have many drawbacks. Often they cannot be used at all in crowded areas, on rocky ground, where the groundwater level is high or in areas periodically flooded. They require access to open ground and the digging of new pits every few years. Flush-and-discharge systems require large amounts of water for flushing, and in many cases, unaffordable investments in pipe networks and treatment plants. Over a year for each person some 400-500 liters of urine and 50 liters of feces is flushed away with 15,000 liters of pure water.

According to World Health Organization, Sanitation can be classified as 'improved' and 'unimproved' as shown in Fig.2.1.

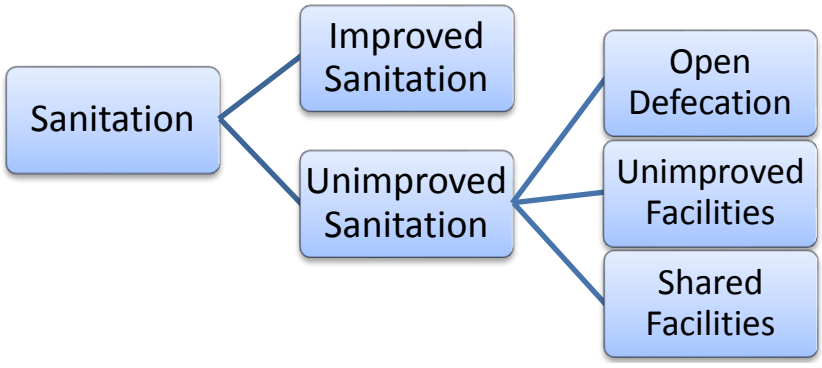


Figure 2.1: **Classification of Sanitation according to WHO**

2.1 Unimproved Sanitation

Systems which are unhygienic and/or lack proper technological inputs to facilitate a minimum comfort level are termed as unimproved sanitation. Following systems fall into this category:

2.1.1 Open Defecation

When human feces is disposed of in fields, forests, bushes, open bodies of water, beaches or on railway tracks or other open spaces or disposed of with solid waste [2].

2.1.2 Unimproved Facilities

These facilities do not ensure hygienic separation of human excreta from human contact. Unimproved facilities include pit latrines without a slab or platform, hanging latrines and bucket latrines [2].

2.1.3 Shared Sanitation Facilities

Sanitation facilities of an otherwise acceptable type shared between two or more households. Only facilities that are not shared or not public are considered improved, by WHO [2].

2.2 Improved Sanitation

Only facilities that are not shared or not public are considered improved, by WHO [2]. These are likely to ensure hygienic separation of human excreta from human contact. They include the following facilities [2]:

- Flush/pour flush to:
    - piped sewer system
    - septic tank
    - pit latrine
- Ventilated improved pit (VIP) latrine
- Pit latrine with slab
- Composting toilet

3. Toilets: Front End of a Sanitation System

The front end of a sanitation system should consist of a toilet or a urinal. A toilet should act as a user interface where people can defecate at ease. It is important to understand the working principle of different types of toilets; some toilets help in conveying the excreta safely, others even treat it on site. Some are dry whereas others use water to convey the waste. In this section different types of toilets are described and their advantages and disadvantages are discussed.

3.1 Pit Latrine

The pit latrine is one of the cheapest and most widely used toilets. It is essentially a pit in which excreta and anal cleansing water are disposed. The pit is enclosed by a superstructure to ensure privacy (see Fig. 3.1). To prevent people of falling into the pit, increase convenience and reduce odor, a slab with a hole is used to cover the pit. A toilet seat can be installed over the slab. [9] As the pit fills, two processes limit the rate of accumulation; leaching and degradation. Urine and anal cleansing water percolate into the soil through the bottom of the pit, while microbial action degrades part of the solid excreta. For this reason, the bottom of the pit should be necessarily unlined [3].The pit latrine needs no water for its function. This is a big advantage in water scarce areas.

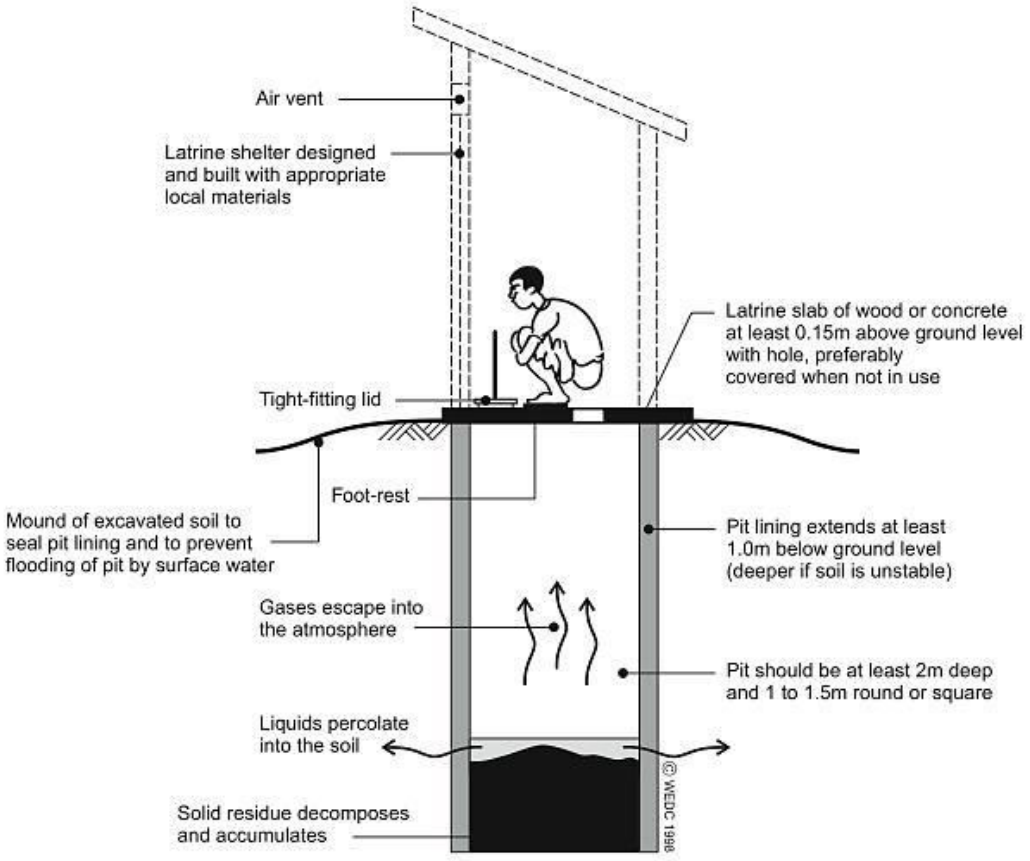


Figure 3.1: Schematic diagram of a simple pit latrine. Source: Harvey et al. 2002 [12]

The depth of the pit is at least 2 m, but usually more than 3 m [4].The depth is usually limited by the groundwater table or rocky underground. Lining the pit walls prevents it from collapsing and provides support to the superstructure [13].Because of the static properties, a round pit with a diameter of more than 1.5 m guarantees a stable construction and avoids a collapse [10].A horizontal distance of 30 m between the pit and a water source like a shallow tube well is recommended to limit chemical and biological contamination of water [3].The WHO (1992) advises a minimum of 15 m distance between a pollution source and a

downstream water abstraction point. In densely populated areas with many pit latrines, the risk of a groundwater contamination remains extremely high [11].

A pit latrine has to be closed after the pit fills up. After six months or so, the degraded fecal matter in the pit may be removed and the latrine put back in operation. A twin-pit latrine is a slight improvement on the pit latrine. In such a latrine, two adjacent pits are constructed. When one pit fills up, it is closed and the second pit is put in operation. The first pit may be cleaned after some time and put back into operation after the second pit fills up. In this way, the latrine is in constant use. However in general, the pit latrine represents a primitive technology and other better non-flush systems are available [3, 13].Advantages and disadvantages of pit latrines is summarized in Table 2.1.

Table 3.1 Advantages and disadvantages of a Pit Latrine [9]

Advantages	Disadvantages
✓ Does not require a constant source of water	❖ Flies and odors are normally noticeable
✓ Low (but variable) capital costs depending on materials	❖ Low reduction of pathogens
✓ Can be used immediately after construction	❖ Costs to empty may be significant compared to capital costs
✓ Can be built and repaired with locally available materials	❖ No specific reuse of feces and urine
	❖ Pits are susceptible to failure/overflowing during floods
	❖ Stagnant water in pits may promote insect breeding
	❖ Sludge requires secondary treatment and/or appropriate discharge

3.2 Ventilated Improved Pit (VIP) Latrine

A ventilated improved pit (VIP) is slightly more expensive than a pit latrine, but greatly reduces the nuisance of flies and odors, while increasing comfort and usability [3]. Fly and odor nuisance may be substantially reduced if the pit is ventilated by a pipe extending above the latrine roof, with fly-proof netting across the top (see Fig. 3.2). The inside of the superstructure is kept dark. Flies that hatch in the pit are attracted to the light at the top of the ventilation pipe. When they fly towards the light and try to escape they are trapped by the fly-screen and die. A small gap above the door or a louver in the door allows the air to enter. The flow of air is increased if the doorway of the superstructure faces the prevailing wind [10].

The VIP design can be used for both single and double pit latrines. Single pits need to be emptied or relocated when full. When double pits are used, one side is used at a time until it

is full and then the second side is used. In this way, no new pits need to be constructed [10].Also, it should be possible to dig out a filled pit only after it has stood for a year or more resulting in an advanced degradation of the content and thus reduced odor and health risk during the emptying. A urine diversion slab could be added to collect and store urine and reuse it in agriculture. If the emptied fecal sludge is composted it may be also reused in agriculture [11].

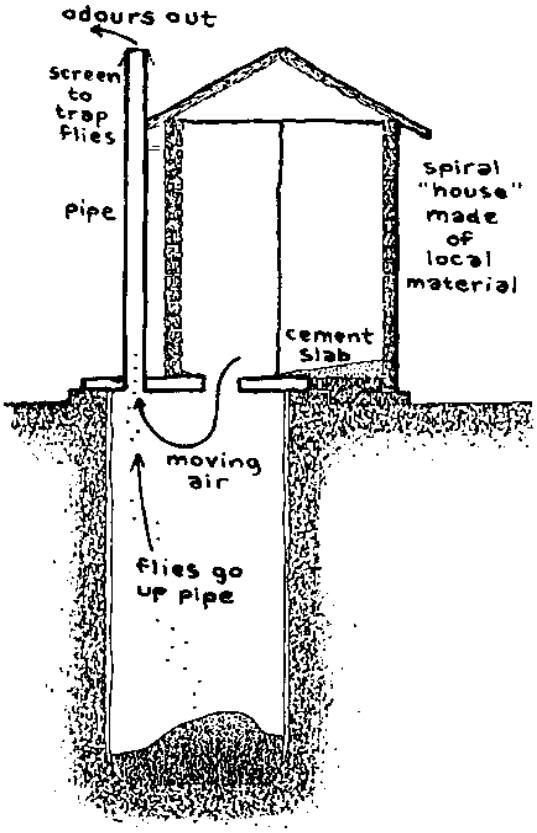


Figure 3.2: Schematic diagram of a Ventilated Improved Pit Latrine
Source: http://www.ugandanetwork.org.uk

Pathogen reduction and organic degradation is very low in such latrines. However since the excreta is confined, pathogen transmission to the user is limited. This technology is a significant improvement over single pit latrines or open defecation [11]. The advantages and disadvantages of a VIP latrine is summarized in Table 3.2.

3.3 Composting Toilet

Composting toilets minimize water use and recycle nutrients contained in excreta. There are various systems i.e. pits or vaults; urine diversion or normal; low-tech and high-tech; single-vault continuous or multiple vault batch. The functioning of the various different composting toilet systems is basically the same (see Fig. 3.3). Fecal matter and toilet paper or other dry cleansing material is dropped into a composting chamber. Organic household waste can also be added. Good ventilation serves to prevent excessive humidity and odor.

Table 3.2 Advantages and disadvantages of a Ventilated Improved Pit Latrine [11]

Advantages	Disadvantages
✓ Flies and odors are significantly reduced (compared to non-ventilated simple pit latrines) ✓ Can be built and repaired with locally available materials ✓ Can be used immediately after construction ✓ Low (but variable) capital costs depending on materials ✓ Does not require a constant source of water	❖ Pits are susceptible to failure/overflowing during floods ❖ Stagnant water in pits may promote insect breeding ❖ Sludge requires secondary treatment and/or appropriate discharge ❖ Leachate can contaminate groundwater ❖ Costs to empty may be significant compared to capital costs ❖ Health risks from flies, if not completely removed by ventilation ❖ No specific reuse of feces and urine ❖ Manual emptying of the pit poses severe health hazard

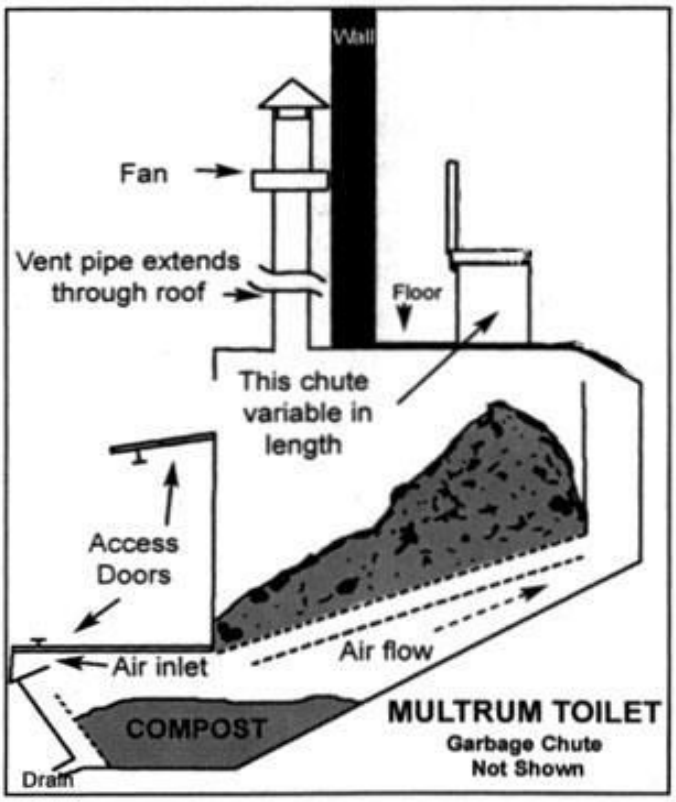


Figure 3.3 General schematic diagram of a Composting Toilet
Source: Adapted from the Humanure Handbook

To increase composting properties, dry material, such as sawdust or ash are added. This regulates the carbon to nitrogen ratio (C/N) and enhances the composting process. If ash and lime are used as bulking material, there is the additional beneficial effect of raising pH, which leads to improved pathogen die-off [14].

Often, composting toilets also have a drainage system to allow the drainage of liquids. This leachate has very high concentrations of nutrients, organics but also contain pathogens. It needs to be collected, treated and if possible reused. Urine diversion usually reduces leachate production [15].The end product of composting toilet is an odorless (and generally stabilized) material, called humanure, which is a valuable as soil conditioner (improving nutrient content, structure and water retention capacity of the soil). Depending on the local conditions, humanure can be harvested after some weeks or years. After this, it may be directly reused or may require a secondary treatment for complete pathogen removal [16].

Ventilation of composting toilets is important in order to maintain low moisture content of the compost and to prevent odor. It can be done naturally or mechanically. Mechanical ventilation requires a fan or another mechanical device and power/solar energy. For natural ventilation, a difference of pressure (or temperature) is required inside and outside the vaults. This can be given by wind or a stack effect. The stack effect can be achieved by installing the ventilation pipe outside and expose it to the sun (it may also be painted in black). When the air in the pipe heats up, it rises upwards out of the vent; a downward draught of cooler air of higher density then flows in through the squat plate hole, replacing the vacuum space created after warm air rising [17].

Composting latrines may be classified as shown in Fig. 3.4 into single vault and multiple vault systems.

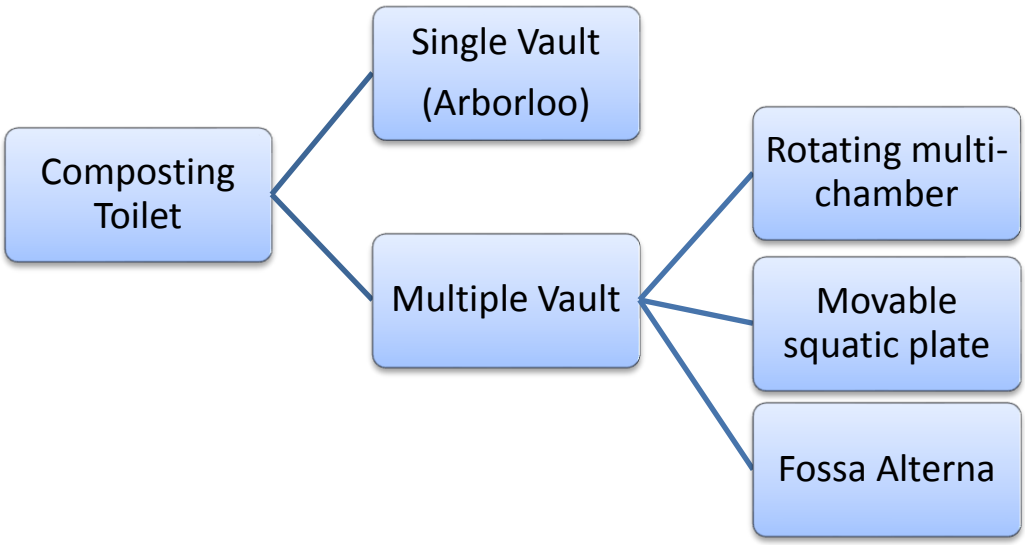


Figure 3.4 Classification of Composting Toilets, according to GTZ, 2010 [15]

3.3.1 Arborloo

This is an extremely simple, low cost version of the single vault composting toilet and has been developed for rural African regions [18]. The Arborloo (see Fig. 3.5) dispenses with the need to remove the compost and instead uses a shallow pit with a depth of up to 1.5 m to collect and compost feces, soil, wood ash and dry leaves. When the pit is almost full the contents are covered with a thick layer of soil. A young fruit tree is eventually planted within the pit. At the same time another shallow pit will be dug and the toilet superstructure moved to the new pit.

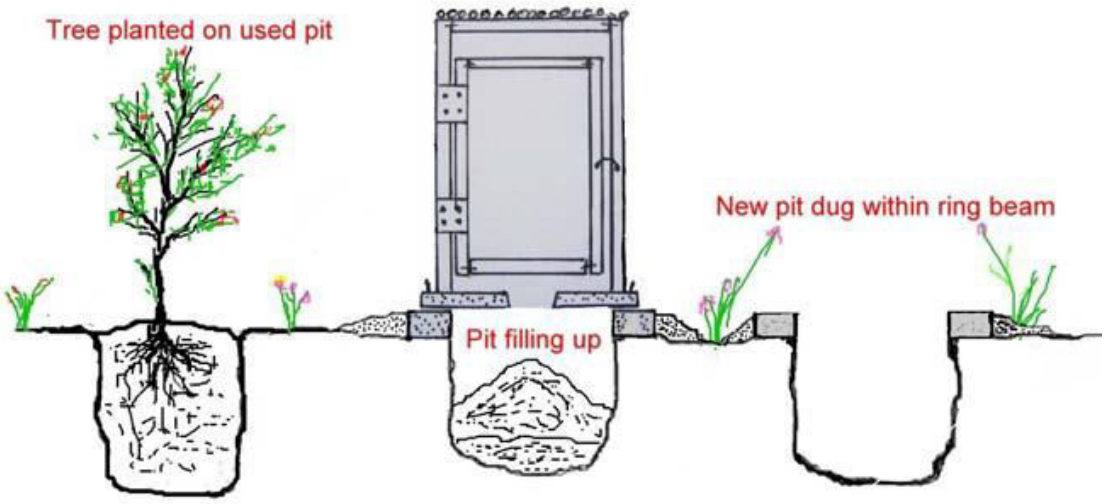


Figure 3.5 The simplest single pit compost toilet–Arborloo, Source: Morgan, 2007[18]

3.3.2 Rotating Multiple Chamber

This is a multiple-vault toilet that can be constructed from an under-floor processing vault with a cylindrical outer housing in which a slightly smaller inner tank is able to rotate. The inner tank is divided into four (or more) chambers (see Fig. 3.6). The vault in use is positioned directly below the down pipe of the toilet. When the vault in use is filled, the inner tank is rotated, whereby the next vault is positioned below the toilet. In this way each vault is filled in sequence. After filling all the vaults, the material in the first vault is removed and emptied through an access door [15].

3.3.3 Movable Squatting Plate

This is a multiple-vault toilet that can be constructed from an under-floor processing vault with a cylindrical outer.In these specially designed double vault systems, the toilet itself is movable. Usually these toilets are squat toilets with a movable squatting plate. The squatting plate is placed above the vault in use, and has an opening for the feces. At the same time the opening of the second, remaining vault remains covered by the squatting plate. Once the first vault is filled the squatting plate of the toilet is turned by 180°, whereby it closes the first vault and opens the second vault for further use [15]. In toilets where urine

is not diverted, liquid can drain into a collection tank by means of a sieve bottom or a slope. If not treated and used as a fertilizer, the leachate should be discharged into an evapo-transpiration bed or a wastewater treatment process. The covering lids of the vaults can face the sun for additional heating. This increases evaporation of leachate as well as the temperature of the composting process [15].

Figure 3.6 Rotating multi-chamber bin, Source: Ekolet, Finland

3.3.4 Fossa Alterna

A low-cost double vault composting toilet, the "Fossa Alterna", has been developed for rural Africa, which functions in exactly the same manner as more expensive systems, only that the composting vaults are shallow pits and the toilet superstructure is moved back and forth between the pits as they are used in alternation [18].

The advantages and disadvantages of composting toilets are summarized in Table 3.3.

3.4 Urine Diversion Dehydration Toilet (UDDT)

Present-day designs of double-vault Urine-Diversion Dehydration Toilets (UDDTs) are based on the Vietnamese double-vault dry toilet, which was developed in the 1960s by local authorities [19].UDDTs divert all liquids i.e. urine and anal cleansing water, from the feces to keep the processing chamber contents dry. UDDTs make use of desiccation (dehydration) processes for the hygienically safe on-site treatment of human excreta. Typical UDDT toilets are shown in Fig. 3.7. Adding wood ash, lime, sawdust, dry earth etc. after defecation helps in lowering the moisture content and raising the pH. The system thus creates conditions of dryness, raised pH and pathogen die-off [19].If wet anal cleansing habits prevail in a

community, anal cleansing water must be diverted (by providing a separate washbowl) from the feces.

Table 3.3 Advantages and disadvantages of a Composting Toilet [16]

Advantages	Disadvantages
✓ Considerable reduction in the volume of fecal matter (upto 30 %, GTZ 2006) ✓ Considerable reduction in the volume of solid waste, as organic waste can be added to the toilet ✓ Urine can be collected separately ✓ There is no need to dig pits or to install sewers in the case of vault composting toilet ✓ The humanure (end product) is a valuable soil conditioner	❖ Needs careful operation and requires bulking material ❖ Proper moisture and temperature needs to be maintained ❖ Secondary treatment of leachate is required ❖ Costlier than ordinary pit latrine

Urine is collected in containers for direct use, storage and further processing (e.g., desiccation, struvite production, etc.). Disinfected urine can be used at small or at large scale, or locally discharged by infiltration into the soil (e.g. evapo-transpiration bed). Feces collected in UDDTs can either be dehydrated (storage and dehydration) or composted (co-composting small-scale or large scale) before they are used as soil amendment [20].

With double-vault UDDTs, fecal matter is collected and stored in twin-pit compartments, which are used alternately. Daily deposits are made into one of the compartments. After each use, a handful of cover material (wood ash, sawdust, soil, lime, etc.) is sprinkled over the feces to absorb moisture and help in speeding up the dehydration process. When one vault is full (which should take roughly one year), the respective compartment is sealed while the other compartment is put in use. The storage time is counted from the date of the last fecal matter contribution to a compartment, and should be at least one year to provide sufficient time for desiccation and disinfection [20].

Plant ash, lime, dried soil or sawdust is added after every defecation as bulking agent to enhance the drying process [14]. The immediate coverage of the fresh feces with an additive material can considerably lower nuisances caused by odor or flies. Faster drying also means that the biological degradation is small if sufficient additive is used and thus, the losses of organic matter and N from the feces to the air are small [14].Ash and lime have the additional beneficial effects of raising pH, which leads to improved pathogen die-off [14].

(a) (b) (c)

Figure 3.7: (a) Double-vault urine diversion dehydration toilet, Vietnamese style, Bhutan. Source: WAFLER (2009); (b) Urine-diversion squatting pan with anal cleansing water collection bowl (made from fibre-reinforced plastic). Source: WAFLER (2010); (c) Ceramic urine-diversion pedestal with separate bowl for collection of anal cleansing water. Source: UNESCO-IHE

UDDTs are waterless systems that are particularly suitable for conditions where water is scarce or expensive. The products of UDDTs, collected urine and humanure, are both valuable fertilizer and need to be either reused correctly on-site or transported to a site where they can be reused or discharged correctly. Therefore, UDDTs are particularly adapted for households or communities with need for such types of fertilizing products. The advantages and disadvantages of UDDT systems are summarized in Table 3.4.

Table 3.4: Advantages and disadvantages of UDDT [20]

Advantages	Disadvantages
✓ Suitable for hard rock soil areas, high ground water levels and areas prone to flooding	❖ Double-vault UDDTs require large surface area for construction
✓ No contamination of groundwater sources due to contained processing of human feces	❖ Possibility of smell if not well operated and too much liquid (urine, anal cleansing water, etc.) enters the processing compartment
✓ UDDTs allow for an easy treatment and reuse of excreta	❖ Transport of human excreta to secondary storage and/or processing site may be required
✓ Urine can be directly used as a fertilizer	❖ Regular shifting of containers from single-vaults
✓ Single vault is easy to construct	❖ It is difficult to use for small children
✓ Saves a lot of water	

3.5 Flush Toilet

A flush toilet is a toilet that disposes off human excreta by using water to flush away the excreta through a drainpipe to another location. It consists of a toilet bowl and a cistern which stores water (see Fig. 3.8). By pushing or pulling lever water is released into the bowl, which mixes with the excreta and carries it away. There are different low-flush toilets currently available that use only a minimized amount of water per flush. A good plumber is required to ensure that all valves are connected and sealed properly, therefore minimizing leakage [3]. To save water, there are dual flush toilets available, with two different flush volumes to reduce water use [4]. But generally the user ends up flushing twice in case of low flush volume. There are also flush toilets in the market that collect the urine separately and use a very low flush volume to flush the urine away [5].

The toilet bowl consists of a siphon including the water seal against bad odors from the effluent pipe. Major advantage of flush toilet is that the smelly feces and urine is easily eliminated by simply using the flush and a water seal [6].

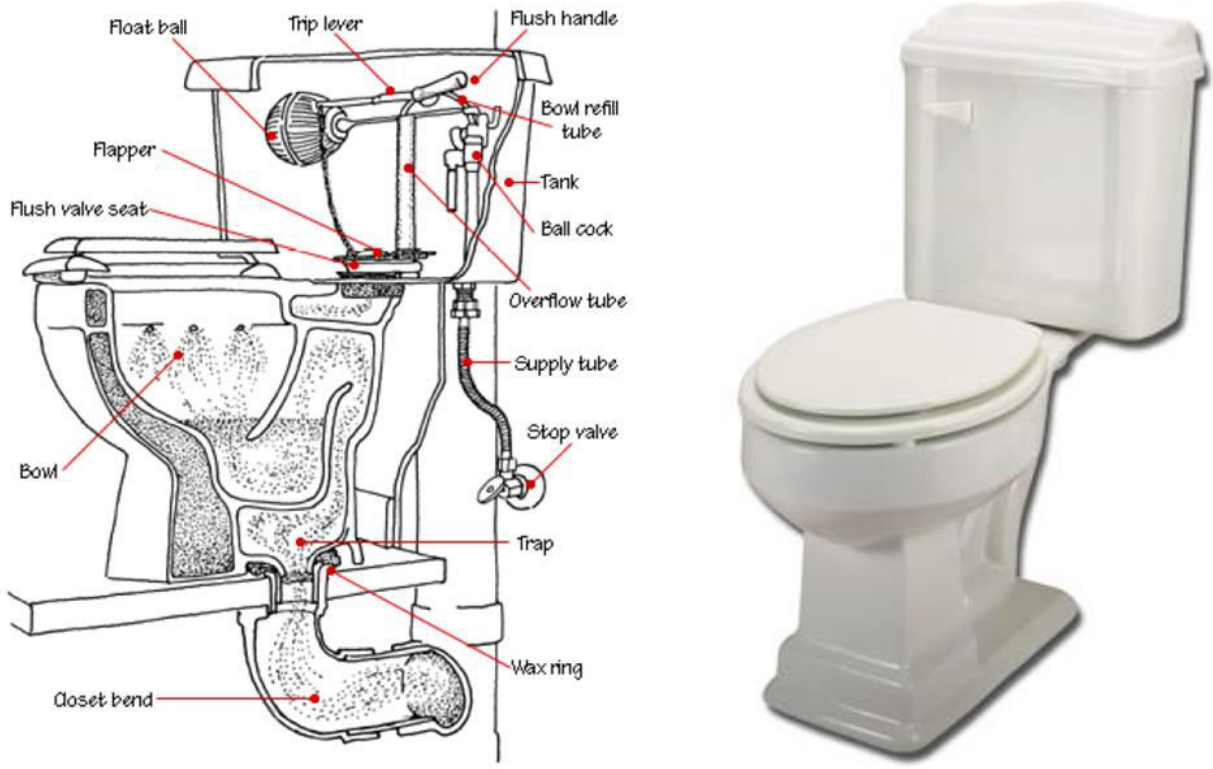


Figure 3.8: Design of a Flush Toilet, Source EAWAG/SANDEC, 2008 [13]

The flush toilet has a good user interface, is hygienic and hence is widely used. However, proper treatment of the sewage generated through flushing is an ecological necessity, which is overlooked in many cases. Besides the fact that a huge amount of freshwater is required for flushing, in many instances there is no treatment plant at the end of a sewerage system.

Consequently, sewage flows directly into water bodies like rivers, lakes, sea or infiltrate into the groundwater and contaminate these water sources [6].

In an article Sunita Narain, a prominent environmentalist in India, describes cistern flush toilets and sewerage as a part of the environmental problem and not as a solution: "Consider the large amount of clean water that is used to carry even a small quantity of human excreta. In India, flushes are designed to be particularly water-wasteful. So with each flush, over 10 liters of clean water goes down the drain. We build huge dams and irrigation systems to bring water to urban areas. This water which is flushed down the toilet goes into an equally expensive sewage system, all to end up polluting more water — invariably our rivers and ponds. Most of our rivers are today dead because of the domestic sewage load from cities. We have turned our surface water systems into open sewage drains" [7].

The various advantages and disadvantages of flush toilets have been summarized in Table 3.5.

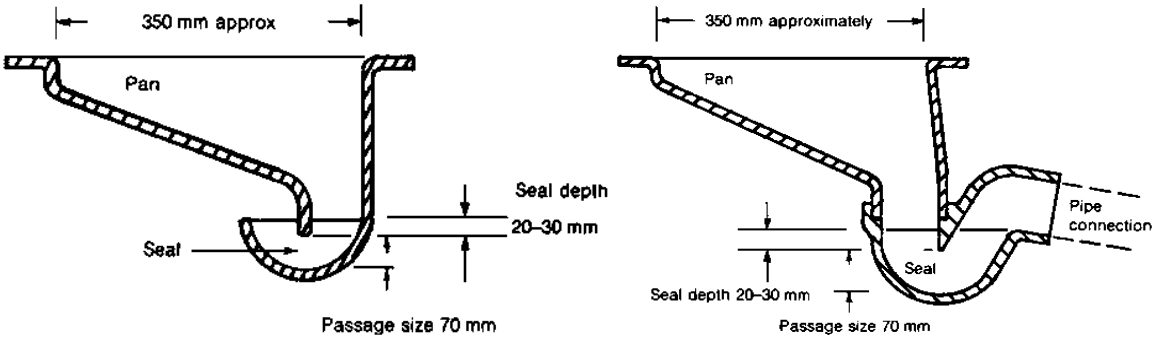
Table 3.5: Advantages and disadvantages of a Flush Toilet [6]

Advantages	Disadvantages
✓ The excreta of one user is flushed away before the next user arrives ✓ If used properly, there is no real problems of odor ✓ Suitable for all types of users namely sitters, squatters, wipers and washers [3] ✓ Easy to use and clean	❖ Capital investment is high; operating cost depends on the price of water and the price of wastewater treatment ❖ It will not function without a constant source of water ❖ Cannot be built and/or repaired locally with available materials ❖ Generates a large volume of sewage to be discharged ❖ There is a high risk of water pollution due leakage in sewer system or if there is no treatment of discharged toilet wastewater

3.6 Pour Flush Toilet

A pour-flush toilet is like a regular flush toilet except that instead of the water coming from the cistern, user has to pour it (see Fig. 3.9). When the water supply is not continuous, any cistern flush toilet can become a pour-flush toilet [8].There is a water seal in such toilets that prevents odors and flies from coming back up the drain pipe. The pan may be of the squatting type or of the pedestal variety where the user can sit.

The amount of water needed for flushing depends on the design of the pan or pedestal, the depth and volume of the water seal, and the minimum passage size through the seal. For a water seal directly above the pit about 1 liter of water is normally sufficient for flushing. For an improved pedestal pan and offset pit, a minimum of 3 liters for water is necessary.



(a) (b)

Figure 3.9 Design of a pour flush toilet. (a) Direct Pour Flush; (b) Offset Pour Flush Source: WHO, 1992[10]

The pour-flush toilet prevents users from seeing or smelling the excreta of previous users. Thus, it is generally well accepted. Provided that the water seal is working well, there should be no odors and the toilet should be clean and comfortable to use [8]. Advantages and disadvantages of pour-flush toilets have been summarized in Table 3.6.

Table 3.6: Advantages and disadvantages of a Pour Flush Toilet [8]

Advantages	Disadvantages
✓ The water seal effectively prevents odors	❖ Requires a constant source of water (can be recycled water and/or collected rain water)
✓ The excreta of one user is flushed away before the next user arrives	❖ Cannot be built and/or repaired locally with available materials
✓ Suitable for all types of users (sitters, squatters, wipers and washers)	❖ Requires some education to be used correctly
✓ Low capital costs; operating costs depend on the price of water	

3.7 Zero Discharge Toilet (ZDT) System

This technology, developed by IIT Kanpur, concerns a flush toilet that is also zero discharge. The toilet is identical to conventional Flush Toilet System, difference being it uses recycled water to flush. A solid liquid separator is fixed underneath the toilet seat, which separates the solid and liquid. The separator allows formation of a thin water film that adheres to the surface of the separator and flows outwardly while most of the solids gravitate into the central retention compartment of the Retention cum Polishing (RCP) tank (see Fig.3.10).

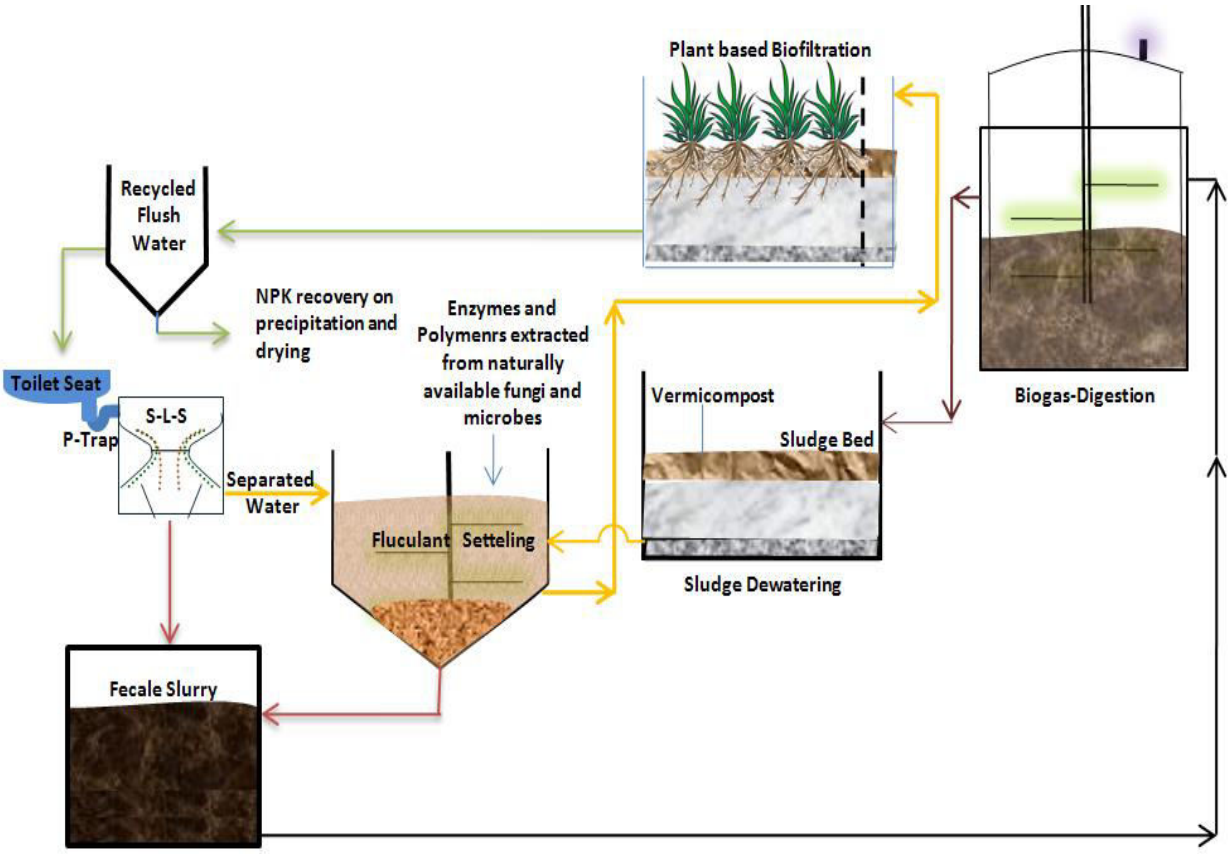


Figure 3.10: Schematic diagram of Zero Discharge Toilet System

Specially developed microbial culture, enzymes and polymers, extracted from naturally available fungi, is added to the separated liquid to eliminate any foul odor. Green non-toxic dye is also added to improve aesthetics of the water. This liquid is then recycled for flushing the toilet, thus avoiding the excessive use of fresh water for flushing while no compromise is done on using adequate liquid for completely flushing the toilet pan.

The solids gradually disintegrate to form slurry, which is then evacuated from the tank under gravity. The fecal slurry is converted into quality organic manure using activated aerobic composting and vermin-composting for rapid and effective utilization of valuable organics and nutrients.

The entire scheme is implemented in a most compact fashion in the vicinity of the toilet avoiding long distance conveyance of water and wastes. The advantages and disadvantages of a ZDT system are summarized in Table 3.7

Table 3.7: Advantages and disadvantages of a Zero Discharge Toilet System

Advantages	Disadvantages
✓ Saves a lot of fresh water, only uses 1/10 of water as compared to conventional flush toilet system ✓ Recovery of valuable by products in the form of organic manure and inorganic fertilizer ✓ No need of sewerage system, soak pit or septic tank and can be easily installed in congested colonies ✓ User comfort and hygienic conditions at the same level as in conventional water borne systems	❖ One dedicated attendant is required for smooth running of the system ❖ Proper maintenance is required otherwise flush water may start smelling

4. Disposal: Back End of a Sanitation System

The back end of a sanitation system can be onsite storage and treatment of excreta or conveyance of excreta to a treatment plant. Following are some of the examples of back end solutions of a sanitation system.

- Piped Sewer System
- Septic Tank
- Anaerobic Baffle Reactor
- Soak Pit
- Composting
- Small Bore Sewer System

4.1 Piped Sewer System/ Conventional Sewers

Conventional gravity sewers are large networks of underground pipes that convey black water, brown water and grey water from individual households to a centralized treatment facility by gravity. Sewer networks are mostly found in urban areas. The sewage from one or more buildings is collected using laterals, usually of 100 mm in diameter. Laterals lead to branch sewers, then main sewers and finally trunk sewers, which is connected to a sump well. Water from the sump well is pumped to the sewage treatment plant [22].

Conventional gravity sewers do not require on-site pre-treatment or storage of the wastewater. Because the waste is not treated before it is discharged, the sewer must be designed to maintain self-cleansing velocity (i.e. a flow velocity that will not allow particles to deposit in sewers). Self-cleansing velocity is taken as 0.6 m/s corresponding to the peak

flow rate in the sewer. A constant downhill gradient must be guaranteed along the length of the sewer to maintain such flows. When the sewer depth becomes too large, intermediate pumping stations are required.

Sewers are laid beneath roads, at minimal depths of 1.5 to 3 m to avoid damages caused by traffic loads. Sewers can be accessed through manholes for cleaning purposes. Manholes are provided at regular intervals along the sewer, at pipe intersections and at changes in pipeline direction. The sewer network requires robust engineering design to ensure that a self-cleansing velocity is maintained, that manholes are placed as required and that the sewer line can support the traffic weight. The advantages and disadvantages of a piped sewer network are summarized in Table 4.1.

Table 4.1: Advantages and disadvantages of a Piped Sewer Network [22]

Advantages	Disadvantages
✓ Convenience to the end user	❖ High capital investment
✓ Health risk is reduced	❖ Needs a continuous and reliable supply of piped water
✓ No nuisance from smells, mosquitoes or flies	❖ Difficult to construct and costly to maintain in high-density areas
✓ Moderate operation and maintenance costs	❖ Problems associated with blockages of pipes and breakdown of pumping equipment may occur
✓ No problems related to discharging wastewater	❖ Recycling of nutrients and energy becomes difficult

4.2 Septic Tank

The septic tank is the most common small-scale decentralized treatment unit for grey water and black water from cistern or pour-flush toilets. It is basically a sedimentation tank in which settled sludge, i.e., fecal matter is stabilized by anaerobic digestion (see Fig.4.1). Dissolved and suspended matter leaves the tank more or less untreated. The shape of a septic tank can be rectangular or cylindrical.

Septic tanks are used for wastewater with a high content of settleable solids, typically for effluent from domestic sources, but they are also suitable for other wastewater with similar properties [23].

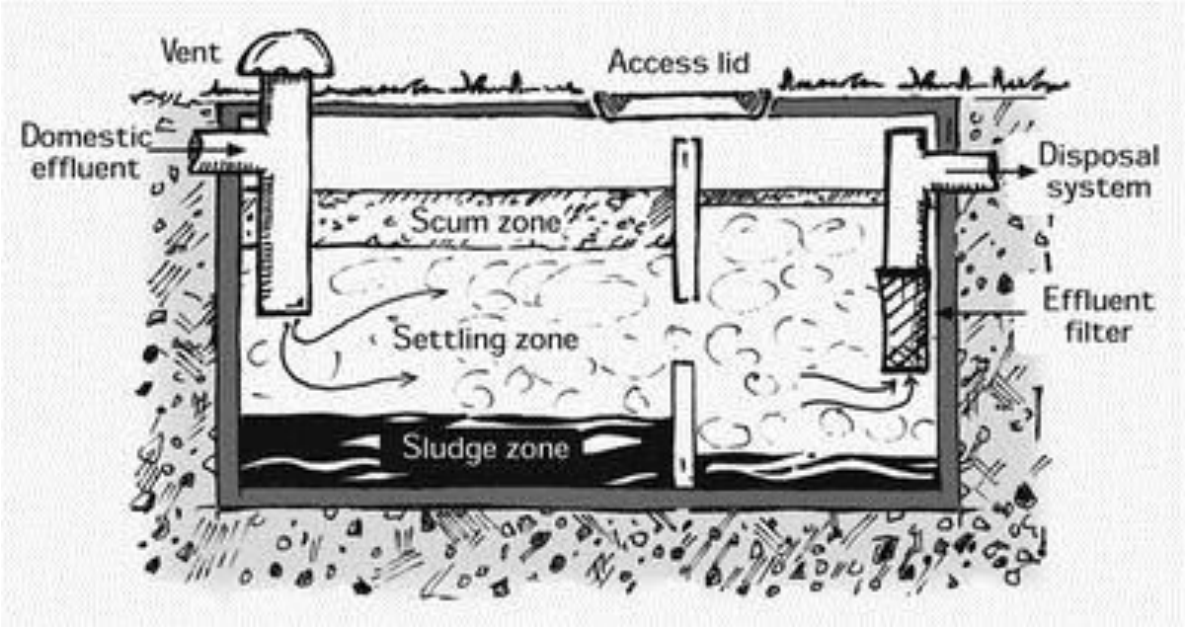


Figure 4.1: Schematic of a Septic Tank, Source: http://www.nrc.govt.nz

A septic tank consists of a minimum of 2 compartments made out of concrete or bricks. Pre-fabricated concrete rings, PVC or fiberglass septic tanks are also available and may be less expensive in some contexts [24].The first compartment occupies at least half of the total volume, because most of the sludge accumulates here [23],while scum (oil and fat) floats to the top. When there are only two chambers, the first one should be 2/3 of the total length [3]. The following chamber(s) are provided to calm the turbulent liquid. A baffle, or the separation between the chambers, is provided to prevent scum and solids from escaping with the effluent [3]. A T-shaped outlet pipe, the lower arm of which is at least 30 cm below water level [23], will further reduce the scum and solids that are discharged. Normally, the chambers are all of the same depth (between 1.5 to 2.5 m), but sometimes the first chamber is made deeper as the others.

Over time, anaerobic bacteria and microorganisms start to digest the settled sludge anaerobically, transforming it into CO_2 and CH_4 (biogas) and some heat. Optimal physical treatment by sedimentation takes place when the flow is smooth and undisturbed. A septic tank will remove 30 to 50% of BOD (Biological Oxygen Demand), 40 to 60% of TSS (Total Suspended Solids) [25]and result in an abatement of 1 log units *E. coli* (a fecal indicator bacteria)[3]although efficiencies vary greatly depending on the influent concentrations and climatic conditions. Hydraulic Retention Time (HRT) is generally 24 hours [27].

The advantages and disadvantages of septic tanks are summarized in Table 4.2.

Table 4.2: Advantages and disadvantages of a Septic Tank [26]

Advantages	Disadvantages
✓ Can be built and repaired with locally available materials ✓ No real problems with flies or odors if used correctly ✓ Little space required due to underground construction ✓ Low investment costs, low operation and maintenance costs depending on the availability of water and the requirement for emptying ✓ No energy required ✓ Long service life	❖ High cost compared to dry or composting toilet systems ❖ Constant and sufficient amounts of piped water required to bring the waste to the treatment unit ❖ Low reduction in pathogens, solids and organics: Secondary treatment for both effluent and fecal sludge required ❖ De-sludging required: Manual de-sludging is hazardous to health and mechanical de-sludging (vacuum trucks) requires the infrastructure and may be rather costly ❖ Only suitable for low-density housing in areas with low water table and not prone to flooding

4.3 Anaerobic Baffle Reactor

Anaerobic baffled reactors (ABR), also called baffled or improved septic tanks, are upgraded septic tanks which aim to enhance the removal efficiency for non-settleable and dissolved solids [27]. An ABR consists of a tank and alternating hanging and standing baffles that compartmentalize the reactor and force liquid to flow up and down from one compartment to the next, enabling an enhanced contact between the fresh wastewater entering the reactor and the residual sludge containing the microorganisms and responsible for anaerobic digestion of the organic pollutants (see Fig. 4.2). The compartmentalized design increases the solids retention time is comparison to the hydraulic retention time, making it possible to anaerobically treat wastewater at short retention times of only some hours [28].The baffled design of the ABR ensures a high solid retention resulting in high treatment rates, while the overall sludge production is characteristically low [29].Such tanks are simple to build and simple to operate, as well as very robust to hydraulic and organic shock loading [23].Yet, both sludge and effluent from ABR still need further treatment before safe discharge into the environment.

It has a settling chamber for larger solids and impurities[23]followed by a series of at least 2 [27], and sometimes up to 5 [23]up-flow chambers. Treatment performance of ABRs is in the range of 65% to 90% COD (Chemical Oxygen Demand) removal, corresponding to about

70% to 95% of BOD (Biological Oxygen Demand) removal [23, 27, 30].This is far superior to that of a conventional septic tank (30 to 50 %) [25].

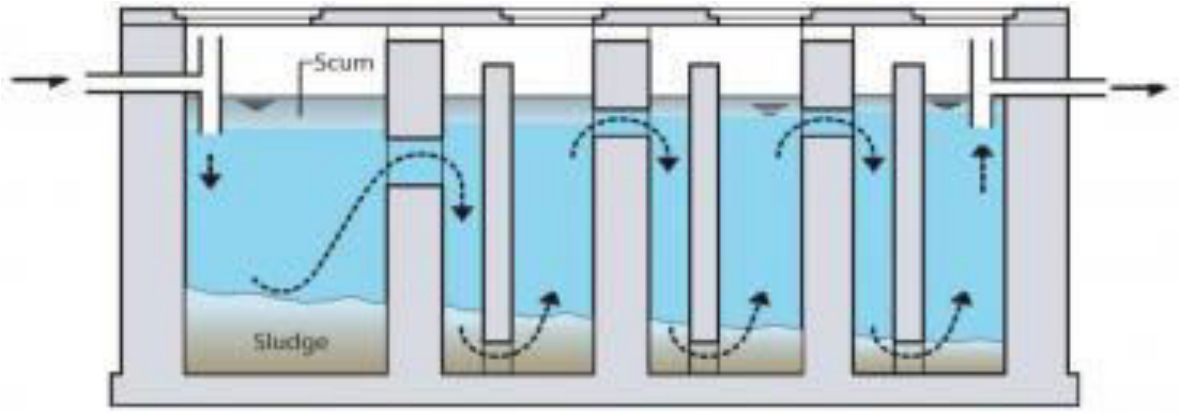


Figure 4.2: Schematic cross-section of an Up-Flow Anaerobic Baffled Reactor Source: Morel and Diener, 2006 [27]

ABRs are typically applied in Decentralized Wastewater Treatment Systems (DEWATS), usually in combination with several other treatment steps. A typical DEWATS could be a five component system of three anaerobic steps consisting of a biogas settler/digester; an ABR and an anaerobic up-flow filter; followed by an aerobic treatment unit such as a constructed wetlands and a maturation pond [31].ABRs are easy to const, low cost and robust [23],yet having higher treatment efficiency than septic tanks. The advantages and disadvantages of an ABR system are summarized in Table 4.3.

Table 4.3 Advantages and disadvantages of an Anaerobic Baffle Reactor[26]

Advantages	Disadvantages
✓ Good treatment performance for all kinds of wastewater ✓ Stable to hydraulic shock loads ✓ Simple to construct and operate, construction material locally available ✓ Low capital and operating costs ✓ Low sludge generation, reduced clogging ✓ Biogas can be recovered, low HRT, long biomass retention time	❖ Needs expert design and construction, Clear design guidelines are not yet available ❖ Long start-up phase ❖ Needs strategy for fecal sludge management (effluent quality rapidly deteriorates if sludge is not removed regularly) ❖ Effluent requires secondary treatment and/or appropriate discharge ❖ Needs water to flush ❖ Low reduction of pathogens

4.4 Soak Pits

Soak pits consist of a simple pit, generally $1m^3$ in volume. The effluent received by a soak pit is allowed to infiltrate into the surrounding soil. The soak pits are either left empty & lined with porous material to provide support and prevent collapse; or they are unlined and filled with coarse rocks and gravel to provide support and to prevent collapsing. In both cases a layer of sand and fine gravel has to be spread across the bottom to facilitate the dispersion of the flow. The depth of a soak pit should be between 1.5 and 4 m. The bottom of the soak pit has to be more than 1.5 m above the groundwater table [32].

As the effluent percolates through the soil from the soak pit, small particles are filtered out by the soil matrix and organics are digested by micro-organisms present in the soil. The effluent is absorbed by soil particles as it moves both horizontally and vertically through the soil pores. Sub-soil layers should therefore be water permeable in order to avoid fast saturation. High daily volumes of discharged effluents should be avoided [33].

A well-sized soak pit should work for about 3 to 5 years without maintenance. To extend the life of a soak pit, care should be taken to ensure that the effluent has been clarified and/or filtered well before it is discharged into the pit. This prevents an excessive build-up of solids. The soak pit should be kept away from high-traffic areas so that the soil above and around it is not compacted. When the performance of the soak pit deteriorates, the material inside the soak pit can be excavated and refilled. To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained. Particles and biomass will eventually clog the pit and it will need to be cleaned or moved. As long as the soak pit is not used for raw sewage, and as long as the previous collection and storage/treatment technology is functioning well, health concerns are minimal. The soak pit is located underground and thus, humans and animals should generally have no contact with the effluent [32].

It is important however that the soak pit is located at a safe distance from a drinking water source (ideally at least 30m). As long as the soak pit is not used for raw sewage, and as long as the previous collection and storage/treatment technology is functioning well, health concerns are minimal [32].

The advantages and disadvantages of a soak pit are summarized in Table 4.4.

4.5 Composting

Composting is a process of decomposing organic matter by microorganisms under controlled conditions. In developing countries the main component of municipal waste is organic matter such as food waste and yard waste. Fecal sludge can also be composted after it has been dewatered using drying beds, thickening ponds, or mechanical dewatering.

Table 4.4: Advantages and disadvantages of a Soak Pit [32]

Advantages	Disadvantages
✓ Low capital cost and requires minimal operation & maintenance ✓ Can be built and repaired with locally available materials and by the community ✓ Small land area required ✓ Simple technique with a high acceptance	❖ Pre-treatment (e.g. settling) of the incoming effluent is required to prevent clogging and limit health risk, although eventual clogging is inevitable ❖ Applicable only where soil conditions allow infiltration, the groundwater table is at least 1.5 m below the soak pit, there is no risk for flooding and any water well is in a distance of at least 30 m ❖ Difficult to realize in cold climates ❖ Should be avoided for high daily volumes of discharged effluents

Dewatered sludge may be mixed at a volumetric ratio of approx. 1(sludge):3 (solid organic material), whereas more liquid sludge (TS of 5 %) may be mixed at ratios between 1:5 to 1:10 [34, 35]. To ensure aerobic conditions, the compost pile is turned twice a week for the first two weeks and then once every 10 days. The temperature of the pile rises to about 65ºC in the first week and then goes down to 40 °C over the next few weeks. After about 21 to 60 days [37],the composting process enters the maturing or curing phase when the pile is left without turning for some weeks or more depending on the local conditions. There are three fundamental types of composting techniques: open or windrow composting; box or bin composting or trench and pit composting [34].

4.5.1 Windrow Composting

This is a slow but simple process. The material is piled up in heaps or elongated heaps (called windrows). The size of the heaps ensures sufficient heat generation, and aeration is ensured by regular turning, addition of bulky materials, passive or active ventilation [34].Systems with active aeration by blowers are usually referred to as forced aeration systems and when heaps are seldom turned they are referred to as static piles. Sloped and sealed or impervious composting pads (the surface where the heaps are located) control the leachate with a surrounding drainage system.

4.5.2 Box Composting

The compost is placed in boxes made out of bricks, wood or mesh boxes with holes in between and a screen at the bottom. Box composting requires less space and is less labor intensive than the windrow system as the aeration is more passively and the compost does not to be turned. But the initial capital cost required for a box system is slightly higher.

4.5.3 Trench and Pit Systems

Theseare characterized by heaps, which are partly or fully contained under the soil surface [34].This allows to save space and to reduce construction cost (in comparison to boxes). Structuring the heap with bulky material or turning is usually the choice for best aeration, although turning can be cumbersome when the heap is in a deep pit and leachate control is difficult in trench or pit composting [34].

4.5.4 Vermi-composting

It involves using special types of earthworms to convert organic waste into worm casting, and can also be done in decentralized composting [36].In a vermi-composting plant, the waste is first composted aerobically for about two weeks as in an ordinary plant. Then, the semi-decomposed waste is put in boxes with special types of worms, such as *Eisenia fetida, Lumbricusrubellus*, and *Eiseniahortensis.* Vermi-composting results in better quality compost, but the worms need more care than aerobic composting. For vermi-composting, the pile does not need turning, but the temperature and moisture needs to be suitable for the worms at all times to ensure their survival.

The advantages and disadvantages of the composting process are summarized in Table 4.5.

Table 4.5: Advantages and disadvantages of Composting [38]

Advantages	Disadvantages
✓ Reduces common problems with organic wastes, such as smell, leachate, flies and rodents, and emissionof methane	❖ If not done properly, household composting can cause problems such as smell, leachate, flies and rodents
✓ Large-scale composting reduces the amount of waste that needs to be transported to final disposal sites, thus reducing the cost of solid waste management	❖ Large-scale composting requires a professional collection, operation and maintenance and marketing ofthe compost
✓ Production and sale of compost will encourage the use of organic farming and gardening and reduce the need for chemical fertilizers	❖ Requires space

4.6 Small Bore Sewer System (SBS)

Small bore sewer system, also known as solids free sewer, divides the sewage into two components at the source itself using an interceptor. One is the decanted liquid fraction (supernatant of the sewage) and the other is settled sewage solids (sludge). The solids which accumulate in the interceptor tanks should be removed periodically for safe disposal. Sewer

lines are designed to receive only the liquid portion of household wastewater for off-site treatment and disposal.

The interceptor tanks are generally designed as septic tanks with minimum two chambers and have to provide space for four separate functions:

(a) Interception of solids;
(b) Digestion of settled solids;
(c) Storage of digested solids; and
(d) Storage of scum

SBS system requires small diameter piping because it conveys only liquid, hence it is economical. Its major advantages and disadvantages are summarized in Table 4.6. Because of the lower costs of construction and maintenance and the ability to function with little water, small bore sewers can be used where conventional sewerage would be inappropriate.

Table 4.6: Advantages and disadvantages of Small Bore Sewer System [39]

Advantages	Disadvantages
✓ Reduced water requirements, since sewers are not supposed to carry any solids	❖ Needs periodic evacuation and disposal of solids from each interceptor tank in the system
✓ Reduced excavation costs, since sewers don't require that much slope, as in the conventional sewer lines	❖ Since the bore is small, there is a possibility of pipe getting choked with floating material
✓ Reduced material costs, as pumps and pipes required are economical as dealing with only liquid	❖ Requires expert design and construction supervision
✓ Reduced treatment requirements, as pretreatment occurs at the interceptor itself	

5. Current Global Sanitation Scenario

Sanitation coverage has lagged behind water provision since the first International Decade of Water and Sanitation (1980-1990). In 2011, almost two thirds (64%) of the world population relied on improved sanitation facilities, while 15% continued to defecate in the open. Since 1990, almost 1.9 billion people have gained access to an improved sanitation facility. The world, however, remains far from the Millennium Development Goal (MDG) sanitation target, which requires reducing the proportion of people without access from 51% in 1990, to 25% by 2015, as agreed upon in the Monterrey Consensus and reinvigorated as part of the "Water for Life" Decade (2005-2015) [2].

By the end of 2011, there were 2.5 billion people who lacked access to an improved sanitation facility. Of these, 761 million use public or shared sanitation facilities and another 693 million use facilities that do not meet minimum standards of hygiene (unimproved sanitation facilities). The remaining 1 billion (15% of the world population) still practice open defecation. The majority (71%) of those without sanitation live in rural areas, where 90% of all open defecation takes place [2].

The toll that unsanitary conditions and contaminated drinking water take on both the health of the human population and the environment is crippling. Besides the indignity suffered by those lacking sanitation facilities, millions of people in the developing world die from diseases contracted through direct and indirect contact with pathogenic bacteria found in human excreta. Infectious diseases such as cholera, hepatitis, typhoid, and diarrhea are waterborne, and can be contracted from untreated wastewater discharged into water bodies. More than half of the world's rivers, lakes, and coastal waters are seriously polluted from wastewater discharge [4].The cost of inadequate sanitation translates into significant economic, social, and environmental burdens.

Some key facts about global sanitation scenario are listed below:

- More than one in six people worldwide - 894 million - don't have access to safe water [2].
- Globally, diarrhea is the leading cause of illness and death, and 88 per cent of diarrheal deaths are due to a lack of access to sanitation facilities, together with inadequate availability of water for hygiene and unsafe drinking water [2].
- Today 2.5 billion people, including almost one billion children, live without even basic sanitation. Every 20 seconds, a child dies as a result of poor sanitation. That's 1.5 million preventable deaths each year [40].
- In Sub-Saharan Africa, treating diarrhea consumes 12 percent of the health budget. On a typical day, more than half the hospital beds in are occupied by patients suffering from fecal-contamination related disease [40].
- A recent study by the Water and Sanitation Program of the World Bank estimates that inadequate sanitation costs India the equivalent of 6.4% of its GDP. A 2008 UNICEF study points out that a mere 21% of rural India uses improved sanitation facilities. But sanitation is no one's priority [41].
- Public health and environmental policies have frequently become exercises in crisis intervention rather than preventive measures that improve the health and well-being of the whole urban population [42].
- Most Asian cities do not have effective wastewater treatment systems. In the Philippines, for example, only 10% of wastewater is treated while in Indonesia the figure is 14%, in Vietnam 4%, and in India 9% [43].

6. Current Indian Sanitation Scenario

In India only 30% of urban households have access to sewerage systems [44].Cities plan for water but not for waste. Growing volumes of untreated sewage leads to contamination of ground water due to leaching. Rivers and tributaries are becoming drains as the time goes by. In 2011 around 40% of urban population did not have access to improved sanitation, and 66% of rural population still practiced open defecation (see Table 6.1). There is no privacy for women who are forced to go out to defecate in open fields, near rivers or on railway tracks at odd hours.

Table 6.1 Use of Sanitation Facilities in terms of percentage of population of India[2]

		Year	1990	2000	2011
		Population (x1000)	873785	1053898	1241492
		Percentage of Urban Population	26	28	31
Urban		Improved	50	54	60
	Unimproved	Shared	17	18	20
		Unimproved	5	6	7
		Open Defecation	28	22	13
Rural		Improved	7	14	24
	Unimproved	Shared	1	3	4
		Unimproved	2	4	6
		Open Defecation	90	79	66
National		Improved	18	25	35
	Unimproved	Shared	5	6	7
		Unimproved	3	5	6
		Open Defecation	74	63	50

Figure 6.1 also clearly depicts the state of sanitation of India in terms of kind of toilets being used, if used at all. By 2011, though there is a rise in percentage of households using better toilet facilities, it is not a significant increase, but the population has increased significantly since 2001 (from Table 6.1). Hence the number of people without improved sanitation facilities is still very high.

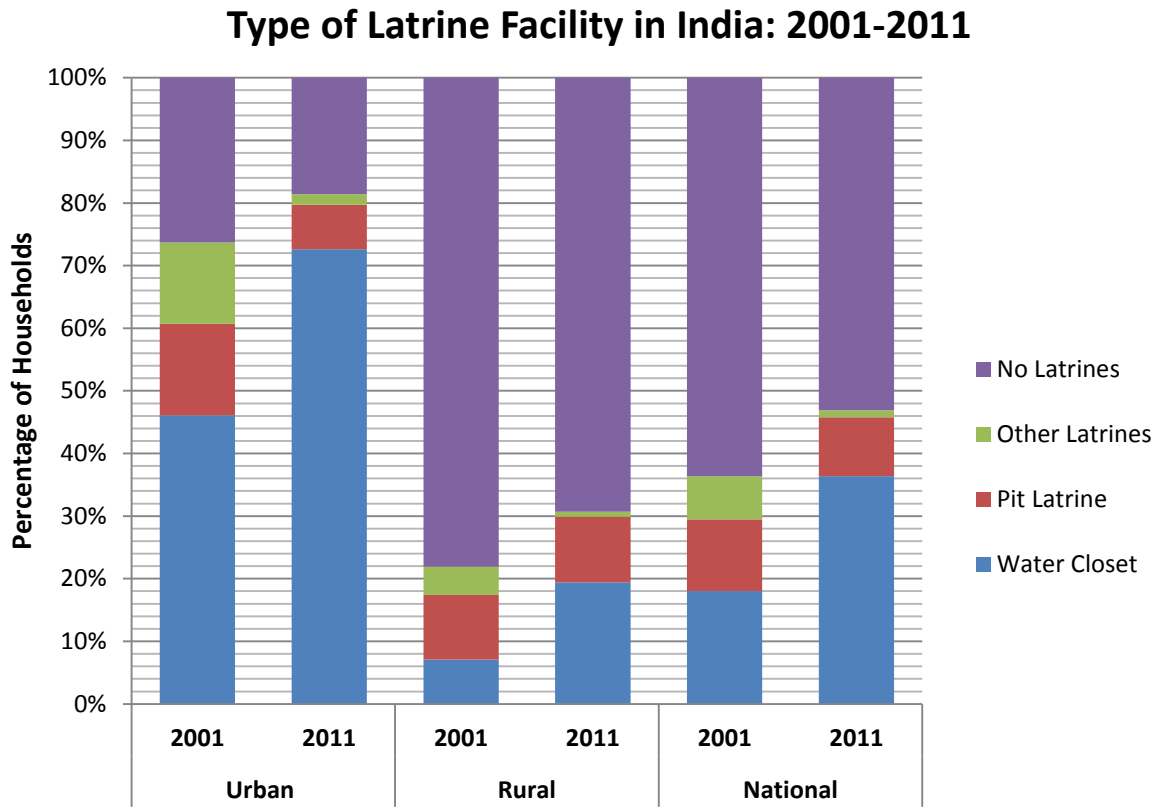


Figure 6.1: Comparison of toilets being used by Indian households in year 2001 and 2011, Source: Census, 2011

7. Crisis in the Making

In India high strength domestic wastewater discharges after no or partial treatment through sewage treatment plants or septic tank seepage have resulted in a large build-up of groundwater nitrates in Rajasthan, India [45]. A study on water handling, sanitation and defecation practices in rural southern India showed that, among 97 households interviewed, 30 (30.9%) had toilets (Septic Tank) but only 25 (83.3%) used them. 74.2% of respondents defecated in fields. This led to serious diarrhea during monsoon and other diseases due to unsafe water [46]. A field survey was conducted in four slums, squatter and pavement dweller communities of Mumbai City, India with a total sample size of 1,070 households. The study revealed extremely low water consumption pattern averaging merely 30 L/capita/d and no sewerage and safe excreta disposal facilities manifested by high occurrence of water-borne diseases. The annual diarrheal, typhoid and malaria cases were estimated to 614, 68 and 126 per thousand populations respectively. At point of prevalence scale, at least 30% of all morbidity could be accounted for by water-related infections [47].

A study was conducted on toilets in elementary and senior secondary schools located in rural areas of six districts of Uttarakhand state in India. In the six districts there were a total

of 705 schools, of which only 372 schools (52.7%) used septic tank. Also, the study revealed that the toilets with septic tanks are 46.2 and 94.2% respectively in economically developed district of Pithoragarh and Udham Singh Nagar. But in economically backward districts of Nainital and Champawat, only 28.6 and 41.9% of elementary and senior secondary schools respectively have toilets with septic tanks. Another finding from the study is that lack of awareness in pupils regarding sanitation was main reason for adverse health effects [48].

Another study discussed the concept of ''healthy city'' which promotes physical, mental, social, and environmental well-being of people [49]. They prioritized urban health and environmental challenges in eight major Indian cities, including Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Meerut, Indore and Nagpur. Based on this criteria different cities in India were evaluated and it was found that Sanitation in Delhi's slums was recorded 23.9% and total of 64%,Mumbai's slums recorded 21.4% and total of 32%, Kolkata's slums recorded 24% and total of 47.1%, and Chennai's slums recorded 19% and total of 34%. The study clearly concludes that there is inadequate sanitation facility in slums and this situation has to change so that the concept of "Healthy City" is achieved [49].

In Assam, the Public Health Engineering Department (PHE) is implementing the Total Sanitation Campaign. The main goal of the Total Sanitation Campaign is to eradicate the practice of open defecation by 2017. Villages that achieve the 'open defecation free' status receive monetary rewards and high publicity under a programme called Nirmal Gram Puraskar. Still there are more than 12 lakh households in Assam which have no access to toilets, as on April 2013. Despite the Total Sanitation Campaign, the practice of open defecation continues in the State. The PHE Department must work rapidly to provide sanitation facilities to these households in order to achieve the ambitious sanitation target under the Total Sanitation Campaign [50].

In an article in the newspaper Hindustan Times about the city of Gurgaon, it is stated that "Poor sanitation leads to rise in diarrhea cases": The first monsoon showers have led to a spurt in diarrhea cases in the city, doctors said. According to private and government hospitals, about eight such cases, along with complaints of gastroenteritis and vomiting, are being reported daily. "The number of patients suffering from water-borne diseases has increased in the past 10 days. We see about 10 patients every day, out of which eight are admitted. These are mostly residents of Sector 14 and areas near the railway tracks where sanitation is a major issue," said DrRakesh Kumar, medical officer, Gurgaon Civil Hospital [51].

An article "Sanitation Shortage Hurts Health, Education of India's Girls and Women" published in GPI[52]states that, "Inadequate sanitation forces women in both rural and urban areas of India to defecate in the open, leaving them vulnerable to sexual violence. Lack of toilets or maintenance of them also creates health hazards. It forces girls to drop out

of school and women to quit their jobs'. Jairam Ramesh, minister of drinking water and sanitation, recently stated in the Parliament that 60% of India's population and 70% of women don't have access to a toilet. In July 2012, he deemed India the world's capital of open defecation, according to local media. He also tempered the excitement about successful missile tests by lamenting that there is no use launching missiles if there are no toilets for women.

The capital of India is also not exempt from the toilet troubles. New Delhi has only 132 public toilets for women, while men have 1,534, according to a 2009 report by the Centre for Civil Society, a nongovernmental research and educational organization devoted to improving citizens' quality of life. Suman Chahar, an expert in environmental sanitation and public health says on open defecation: "This is a very grave and daily issue, particularly for these women, it concerns their security, health and dignity. Along with shocking incidents of rape and molestation and lewd remarks, I have heard shocking stories of what all these women go through if accidentally they found a man from their community 'sitting' next to them in the row." Inadequate sanitation facilities in rural and urban India endanger the safety and health of girls and women as well as force them to drop out of school and quit their jobs. Advocates demand that the government and community prioritize this basic need before pursuing further technological advancements in the country.

8. Concluding Remarks

The discussion presented so far clearly shows that the sanitation problem is far from being solved in India. It is a matter of shame that in our country a large number of people still practice open defecation or have to defecate in conditions that do not provide a minimum amount of dignity and comfort. The matter of scientific disposal of excreta is another area of concern. Currently, unscientific disposal of excreta into water bodies and into the ground is resulting in both our surface and ground water bodies being polluted. Sewage can be plainly seen flowing or accumulating in water bodies and surface depressions and excreta can be seen on the ground in plain view. These things not only violate our aesthetic sense, they also cause odour problems, lead to breeding of disease vectors and are a threat to public health.

The overall sorry state of sanitation facilities in India arises only partly from the fact that a large segment of our population is poor and lack access to toilets. There are considerable doubts regarding which sanitation technologies are suitable for Indian conditions. In recent years, both central and state governments in India have spent enormous resources to provide "improved" sanitation facilities as elucidated in the "Millennium Development Goal" targets. Large numbers of pit latrines were constructed to prevent open defecation. However, many of these pit latrines became defunct and people returned to open defecation.

One of the main reasons for failure of sanitation programs in India is the adoption of solutions which are incompatible with the expectations and cultural sensibilities of the population. Based on the discussion presented about the peculiarities of traditional sanitation practices and present sanitation conditions in India, certain conclusions can be arrived at regarding sanitation practices in Indian conditions,

1. Open defecation cannot be recommended under any circumstances. This practice does not allow defecation with dignity and privacy and may be unhygienic if done improperly.
2. Toilets that need daily manual cleaning are not recommended under any circumstances since they are against human dignity and contravene the Manual Scavenging Act.
3. Hanging toilets, i.e., toilet constructed directly over water bodies or cesspools cannot be recommended under any circumstances. Such toilets create extremely unhygienic conditions.
4. Indian habit of using anal cleansing water renders the use of pit latrines difficult. The pits cannot be maintained dry and this leads to odor and fly problems. Defecation under such conditions becomes uncomfortable, and people soon abandon pit latrines and revert to open defecation.
5. Use of UDDTs is difficult, since the present models require following a certain discipline during defecation. An improved version of UDDT, specially attuned to Indian conditions is required.
6. Flush and pour-flush latrines connected to open drains are problematic. Since the open drains follow the contours of the ground, in flat areas slopes cannot be maintained for flow of sewage at self-cleansing velocities. This leads to the deposition of sewage solids in the drain and subsequent choking and overflowing of the drains, creating unhygienic conditions.
7. Flush and pour-flush latrines connected directly to soak pits or connected to septic tanks followed by soak pits is problematic in congested areas, especially when water table is high. The chances of groundwater pollution are very high under such conditions.
8. Shared or communal toilet facilities must be given due importance. Such facilities may be the only workable solutions under certain conditions.

Hence there is an urgent need for evaluation of all sanitation technologies currently available and to identify and select the best technologies applicable to Indian conditions both urban and rural which should follow a certain level of hygiene and maintain human dignity. Some underlying principles for such analysis can be identified as:

1. The acceptable system must allow defecation in privacy and with dignity and a minimum amount of comfort. In other words, the system must provide a good “front end” solution.
2. The effluents from the sanitation system should not be a threat to general aesthetics of the area, i.e., seen flowing or accumulating in open view or create odor problems. Such effluents should not become a threat to public health, either by allowing proliferation of flies and other disease vectors or by pollution of groundwater.
3. The effluent from the sanitation system must be treated to render it harmless before disposal. In other words, the system must have a good “back end” solution.
4. It is also desirable that the effluent from the sanitation system is treated such that nutrients present in feces and urine can be recycled for land application.

References

1. UNICEF (Editor) (2012): Sanitation and Hygiene Advocacy and Communication Strategy Framework 2012-2017
2. (WHO) World Health Organization and (UNICEF) United Nations Children Fund, Joint Monitoring Programme on Water Supply and Sanitation (2)
3. TILLEY, E.; LUETHI, C.; MOREL, A.; ZURBRUEGG, C.; SCHERTENLEIB, R. (2008): Compendium of Sanitation Systems and Technologies. Duebendorf and Geneva: Swiss Federal Institute of Aquatic Science and Technology (EAWAG).
4. UNEP (Editor) (2002): A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquid and Hazardous Waste for Small Island Developing States (SIDS) in the Pacific Region. The Hague: United Nations Environment Programme (UNEP)
5. UNESCO-IHE (Editor); UNEP/GPA (Editor) (2009): Compendium of Technologies. United Nations Educational, Scientific and Cultural Organization (UNES), Institute for Water Education (IHE) and United Nations Environment Programme Global Programme of Action (UNEP/GPA).
6. STAUFFER, B., Seecon International Gmbh, Flush Toilets, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
7. NARAIN, S. (2002): The Flush Toilet is Ecologically Mindless. In: Down to Earth 19.
8. WAFLER, M.; SPUHLER, D. Seecon International Gmbh, Pour Flush Toilets, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
9. STAUFFER, B.; SPUHLER, D. Seecon International Gmbh, Pit Latrine, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
10. WHO (Editor) (1992): A Guide to the Development of On-site Sanitation. Geneva: World Health Organisation (WHO).
11. STAUFFER, B., Seecon International Gmbh, Ventilated Improved Pit Latrine, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
12. HARVEY, P.; BAGHRI, S.; REED, B. (2002): Emergency Sanitation: Assessment and Programme Design. Loughborough: Water, Engineering and Development Centre (WEDC).
13. EAWAG/SANDEC (Editor) (2008): Sanitation Systems and Technologies. Lecture Notes. Duebendorf: Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and Sanitation in Developing Countries (SANDEC).
14. JOENSSON, H.; RICHERT, A.; VINNERAAS, B.; SALOMON, E. (2004): Guidelines on the Use of Urine and Faeces in Crop Production. Stockholm:EcoSanRes.
15. GTZ (Editor) (2010): Basic overview of Composting Toilets (with and without urine diversion). Eschborn: German Agency for Technical Cooperation (GTZ) GmbH.

16. SPUHLER, D. Seecon International Gmbh, Composting Toilets, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
17. OKETCH, M. (2005): Systems for Enhancing Ventilation for Improved Control of Odor and Fly Nuisance in Dry Urine Diverting Ecological Sanitation Toilets.
18. MORGAN, P.; EcoSanRes (Editor) (2007): Toilets That Make Compost . Stockholm: Stockholm Environment Institute.
19. WINDBLAD, U.; SIMPSON-HERBERT, M. (2004): Ecological Sanitation - revised and enlarged edition. (pdf presentation). Sweden: Stockholm Environment Institute.
20. WAFLER, M.; SPUHLER, D. Seecon International Gmbh, Urine Diversion Dehydration Toilet, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
21. TARE, V.(2006) Environment Friendly Rail Coach Toilet System, In: 8th MICC Meeting of Technology Mission on Railway Safety, Indian Institute of Technology Kanpur, Kanpur, India.
22. FAURE, F. ; SPUHLER, D. Seecon International Gmbh, Conventional Sewers(combined sewers), published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
23. SASSE, L. ; BORDA (Editor) (1998): DEWATS . Decentralized Wastewater Treatment in Developing Countries. Bremen: Bremen Overseas Research and Development Association (BORDA).
24. WSP (Editor) (2008): Technology Options for Urban Sanitation in India. A Guide to Decision-Making. Pdf presentation. Washington: Water and Sanitation Program.
25. UNEP (Editor) (2004): Improving Municipal Wastewater Management in Coastal Cities. The Hague: United Nations Environment Programme Global Programme of Action (UNEP/GPA), Coordination Office.
26. SPUHLER, D. Seecon International Gmbh, Septic Tanks, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]
27. MOREL, A.; DIENER, S. (2006): Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighborhoods. Duebendorf: Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and Sanitation in Developing Countries(SANDEC).
28. EPA (Editor) (2006): Emerging Technologies for Biosolids Management. United States Environmental Protection Agency, Office of Wastewater Management
29. FOXON, K.M.; PILLAY, S.; LALBAHADUR, T.; RODDA, N.; HOLDER, F.; BUCKLEY, C.A. (2004): The anaerobic baffled reactor (ABR)- An appropriate technology for on-site sanitation. In: Water SA 30, 5
30. BORDA (Editor) (2009): EmSan - Emergency Sanitation. An innovative & rapidly installable solution to improve hygiene and health in emergency situations. Bremen: Bremen Overseas Research and Development Association
31. WHO (Editor) (2009): Ecosan Expert Training Course for the Introduction of Ecological Sanitation in Bhutan. Geneva: World Health Organization.
32. GENSCH, R.; SACHER, N. Xavier University, Soak Pits, , published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]

33. HEEB, J.; JENSSEN, P.; GNANAKAN; CONRADIN, K. (2008): Ecosan Curriculum 2.3. Switzerland, India and Norway: seecon international, International Ecological Engineering Society, Norwegian University of Life Sciences, ACTS Bangalore.

34. STRAUSS, M.; DRESCHER, S.; ZURBRUEGG, C.; MONTANGERO, A.; OLUFUNKE, C.; DRECHSEL, P. (2003): Co-composting of Faecal Sludge and Municipal Organic Waste. Swiss Federal Institute of Aquatic Science (EAWAG), Department of Water and Sanitation in Developing Countries(SANDEC) and International Water Management Institute (IWMI).

35. OLUFUNKE, C.; DOULAYE, K. (2009): Co-composting faecal sludge & organic solid waste, Kumasi, Ghana. Eschborn: Sustainable Sanitation Alliance (SuSanA).

36. ZURBRUGG, C.; DRESCHER, S.; PATEL, A.H.; SHARATCHANDRA S.C. (2002): Decentralised Composting An Option for Indian Cities? Report of a Workshop Held in Bangalore India, 4-5 June, 2002. Duebendorf: EAWAG.

37. UNEP (Editor); IETC (Editor) (1996): International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. United Nations Environment Programme (UNEP) and International Environmental Technology Centre Japan (IETC).

38. TULADHAR, B. Environment and Public Health Organization, SPUHLER, D. Seecon International Gmbh, Co-Composting, published on SSWM (http://www.sswm.info/) [Accessed: 13/06/2013]

39. OTIS, R. J., & MARA, D. D. (1985). Technology Advisory Group .The design of small bore sewer systems. World Bank.

40. Water Supply and Sanitation Collaborative Council (WSSCC))

41. Sanitation: A Statistical overview, http://indiasanitationportal.org

42. Chaplin, S. E. (2011). Indian cities, sanitation and the state: the politics of the failure to provide. Environment and Urbanization, 23(1), 57-70.

43. Fast Facts: Urbanization in Asia. ADB, http://indiasanitationportal.org

44. NARAIN S., PANDEY P. (2012), Centre for Science and Environment, Excreta Matters Vol-1

45. Gupta, A. B., & Gupta, S. K. (2001). Simultaneous carbon and nitrogen removal from high strength domestic wastewater in an aerobic RBC biofilm. Water Research, 35(7), 1714-1722.

46. Banda, K., Sarkar, R., Gopal, S., Govindarajan, J., Harijan, B. B., Jeyakumar, M. B., ...&Balraj, V. (2007). Water handling, sanitation and defecation practices in rural southern India: a knowledge, attitudes and practices study.Transactions of the royal society of tropical medicine and hygiene, 101(11), 1124-1130.

47. Karn, S. K., & Harada, H. (2002). Field survey on water supply, sanitation and associated health impacts in urban poor communities- A case from Mumbai City, India. Water Science & Technology, 46(11), 269-275.

48. Kumar, A., &Taunk, A. (2010). A study of sanitation of toilets in elementary and senior Secondary schools located in rural areas of Uttarakhand state in India. International Journal of Sociology and Anthropology, 2(8), 178-184.

49. Goli, S., Arokiasamy, P., &Chattopadhayay, A. (2011). Living and health conditions of selected cities in India: Setting priorities for the National Urban Health Mission. Cities, 28(5), 461-469.

50. Staff Reporter (Guwahati, April 17, 2013): Assam yet to achieve target under Total Sanitation Campaign, published on senitelassam.com, front page.

51. Himabindu Reddy (Gurgaon, June 19, 2013): Poor sanitation leads to rise in diarrhoea cases, published on HindustanTimes

52. FoziaYasin, Reporter – Delhi, (India News Desk, Nov 8.2012): Sanitation Shortage Hurts Health, Education of India's Girls and Women, published on GPI, http://www.globalpressinstitute.org/asia/india/sanitation

53. Vinnerås, B. (2002). Possibilities for sustainable nutrient recycling by faecal separation combined with urine (Vol. 353).

54. Esrey, S. A. (2001). Towards a recycling society: ecological sanitation-closing the loop to food security. Water Science & Technology, 43(4), 177-187.

55. Wolgast, M. (1993). Rena vatten. Om tankarikretslopp. Crenom HB, Uppsala.H. Heinonen-Tanski, Christine van Wijk-Sijbesma, CV Human excreta for plant production, Bioresource Technology, 96, 403-411.

56. MUENCH, E. (2009): Urine-Diversion Dehydration Toilets. Eschborn: German Agency for Technical Cooperation (GTZ) GmbH.