Chapter 9

ON-SITE HUMAN WASTE MANAGEMENT: TECHNOLOGICAL OPTIONS

Introduction/Simple pit latrines/Ventilated improved pit (VIP) latrines/ Reed odourless earth closets ROEC/Compost latrines/Pour-flush sanitation technologies/Aqua-privies/Septic tank system/ Communal sanitation system

9.1 INTRODUCTION

An important reason why sanitation coverage is low in the developing countries compared to water supply is that whenever the designers or planners think of sanitation they mostly think of costly conventional sewerage systems or septic tank systems which most people in the developing world cannot afford. It is only very recently that the concerned authorities in developing countries have realized the need for low-cost sanitation options in order to serve the vast majority of the population. It can be mentioned here that the high-cost conventional sewerage system does not provide for additional health benefits over a properly installed low-cost simple pit latrine; it may only provide more convenience.

Fortunately, there exists a wide range of alternative sanitation technologies that are low-cost, easily maintainable and can be selected to suit different hydrogeological, socio-economic and cultural conditions. This chapter considers a selected range of low- to medium-cost sanitation technologies beginning with the least-cost pit latrine technologies, focusing on their design considerations, merits, demerits and suitability.

9.2 SIMPLE PIT LATRINES

The pit latrines are the most common and simplest form of excreta disposal in many developing countries. These are almost universally acceptable in rural areas and are also widely used in low-income urban communities, although often not appropriate. They are, however, the cheapest system possible and the system most appropriate for individual householders responsible for their own sanitation.

A pit latrine consists of a manually dug or bored hole into the ground, an appropriate seat or squatting slab, and a superstructure erected over it (see Figure 9.1). The pit is simply a hole in the ground into which excreta fall. Urine and other liquids soak into the ground and solid materials are retained and decomposed in the pit.

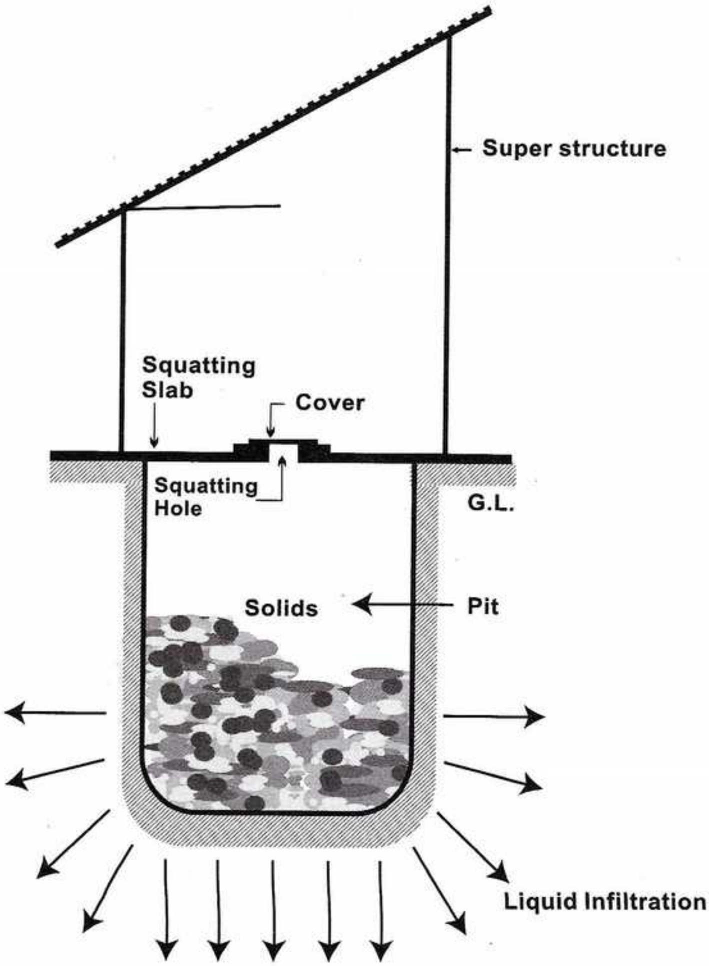

Figure 9.1 Conventional Simple Pit Latrine

There are many different kinds of pit latrines, all of which may not be fully sanitary and hence are not recommended. Simple pit latrines (often called "home-made" latrines as the family members can construct them), though not fully sanitary, are sometimes promoted in order to discourage open defecation and other unsanitary practices. Conventional pit latrines with a basic pit and a shielding superstructure have many disadvantages, odour and fly and mosquito nuisance in particular. For these reasons, improvements are made to make pit latrine technologies more acceptable to users.

With slight modifications in design and with very little intervention, conventional pit latrines can be improved to be hygienic. There are several forms of pit latrines. When excreta fall directly into a pit underneath the user, it is called a *direct pit latrine*. When excreta pass through a short pipe or a channel to a pit a few metres away, it is called an *offset pit latrine*. It may be called a *partly offset pit latrine* when part of the pit is under the shelter and part is outside, where a removable cover allows the contents to be taken out. The most appropriate type of pit latrine, however, depends on the local situation, particularly on the type of materials used for anal cleansing, including the level of the groundwater and the traditions and the choice of the users.

General design considerations for pit latrines

- The pit should be as large as possible. However, it should not be more than 1.5 m wide, otherwise construction of the cover slab will be more expensive.
- Soils with low permeability (below 2.5 mm/hour) are unsuitable for pit latrines as the liquid portion of excreta is unable to infiltrate into the soil.
- Pits in unstable soils must be fully lined, otherwise there is risk that the pit will collapse and the superstructure may fall into it. A wide variety of materials can be used to line the pit; for example, concrete rings, bricks, cement-stabilized soil blocks, masonry, perforated oil drums, etc. The pit can also be strengthened against collapse by putting a ring beam around the upper part.
- Safe distance between the latrine pit and a source of drinking water e.g., tubewell, should be provided in order to allow for sufficient residence time for the pathogens to be eliminated. In absence of information on groundwater flow in horizontal direction, a distance of at least 10.0 m should be provided.

Pit latrine design

Effective Pit Volume: The effective pit volume depends on the solids accumulation rate, the number of users and the desired life of pit. The effective volume can be calculated as:

$$V = C \times P \times N \qquad (9.1)$$

Where,

V = Effective volume of the pit in m^3
C = Solids accumulation rate in m^3/person/year
P = Number of persons who will be using the latrine
N = Design life in years.

The total pit size for a pit latrine not exceeding 4.0 m in depth can be determined, as suggested by Kalbermatten et al. (1980), by the following relationship:

$$V = 1.33 \times C \times P \times N \tag{9.2}$$

The factor of *1.33* is incorporated to ensure a clear space above the remains of the excreta at the end of the design period. The factor will allow 75% of the pit to be full at the end of this period.

Solids accumulation rate, C: Excreta deposited into the pit have two essential components:

- liquid fraction of excreta (mainly urine), together with small amount of water that enters the pit due to anal cleansing and slab washing which ultimately infiltrates into the surrounding soil;
- the faecal solids in excreta that are digested anaerobically to produce (i) gases such as methane, carbon dioxide and hydrogen sulphide which are exhausted from the pit via the squat hole or the vent pipe; and (ii) soluble compounds which are either further oxidized in the pit or are carried into the surrounding soil by infiltrating of the liquid fraction.

In dry pits (not extended below the groundwater table), solids accumulation rates vary between 0.03 and 0.06 m^3/person/year, and in wet pits between 0.02 and 0.04 m^3/person/year. Accumulation rates are lower in wet pits because biodegradation is faster under wet conditions than under the only just moist conditions in dry pits. For design purposes, solids accumulation rates may be taken as 0.04 and 0.06 m^3/person/year in wet and dry pits respectively. The value of C can also be obtained from Table 9.1.

Providing a prefabricated slab with a squatting pan attached to it can be the simplest and cheapest improvement of a conventional pit latrine. For structural stability reinforcement is placed in the slabs. Prefabricated cement slabs in a simple pit latrine prevent transmission of hookworm. A pit lining may be required in loose soils.

Table 9.1 Values of Solids Accumulation Rates (m^3/person/year)

Wet Pit		Dry Pit	
Anal cleansing: water	Anal cleansing: solids	Anal cleansing: water	Anal cleansing: solids
0.04	0.06	0.06	0.09

(Source : Kalbermatten et. al., 1980)

Advantages and disadvantages of pit latrines

The main advantages of a simple pit latrine are:

- least costly;
- easily constructed and maintained;
- structurally safe and therefore free from the risk of children falling into it, and thus less frightening for children;
- prevents hookworm transmission; and
- offers a better solution than open defecation and unhygienic hanging latrines.

The most serious disadvantages of a simple pit latrine are:

- flies lay their eggs in faeces within poorly built latrines. Increase in the fly population increases spread of diseases caused by the faecal pathogens they carry;
- odour nuisance;
- improper lining of pits may lead to collapse of the superstructure.

9.3 VENTILATED IMPROVED PIT (VIP) LATRINES

Ventilated improved pit latrines, commonly known as VIP latrines, are an improvement to overcome the disadvantages of the simple pit latrines. The main problems associated with traditional simple pit latrines, i.e. fly and mosquito nuisance and unpleasant odours, are effectively minimized by the action of a vent pipe, fly screen and a squatting cover in the VIP latrines. The whole system is properly engineered as an effective sanitation option for both rural and urban areas by designing the pit either as a single pit or an alternate twin-pit system, single-pit can be emptied mechanically. In case of a permanent superstructure, an alternating twin-pit system permitting safe manual removal of the digested solids may be installed.

VIP latrine pits receive excreta in the same fashion as those of the simple pit latrines, by direct deposition through a squat hole or a pedestal seat (Figure 9.2). The liquid part infiltrates into the surrounding soil and the faecal solids are digested anaerobically, gradually accumulating and eventually requiring emptying the pit for further use.

Elements of VIP latrines:

The basic elements of a VIP latrine are:

- the pit, which can be either a single pit or an alternating twin-pit; in either case, the pit should be lined with open joint brickwork or prefabricated concrete rings; the lining prevents soil collapse during emptying operations or during heavy rains, and the open joints allow liquids to infiltrate into the soil;
- a cover slab, usually of reinforced concrete, which covers the pit and has two holes - the squat hole and the other for the vent pipe;

- a superstructure for privacy and protection from rain and sun, which can be built according to the choices of the users;
- the vent pipe and the flyscreen which keep the latrine free from flies, mosquitoes, and unpleasant odours.

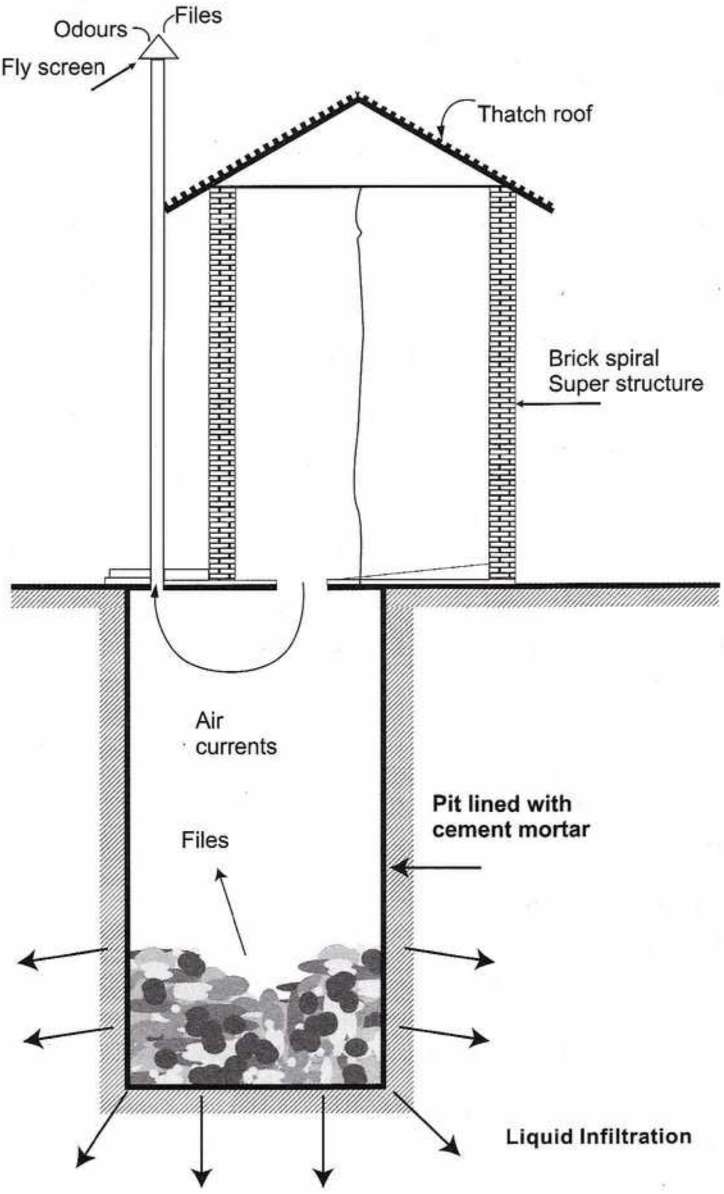

Figure 9.2 The ventilated improved pit (VIP) latrine

Single-pit VIP latrines

Single pit VIP latrines, as shown in Figure 9.2, consist of one pit, a vent pipe and a superstructure and are suitable where mechanical emptying is possible when the pit is full. Manual emptying is not recommended, as the excreta at the top are fresh and potentially dangerous for the emptier. Usually they are designed for a longer life (e.g., ten years) and act as permanent structures.

Alternating twin-pit VIP latrines

Alternating twin-pit VIP latrines have two separate pits, each with their own vent pipe, and the superstructure is located centrally over the off-set pits. The slab covering the pits has two squat holes, one over each pit (Figure 9.3). Only one squat hole and pit are used at a time, the squat hole over the other pit being closed by a concrete plug. When this pit is full, say, after 1-3 years, its squat hole is covered up and the second pit is put into service. After a further period of 1-3 years, when the second pit is full, the contents of first pit are removed and it is put back into service. This alternating cycle continues indefinitely. This type of VIP latrine thus offers a permanent sanitation option suitable for both urban and rural areas.

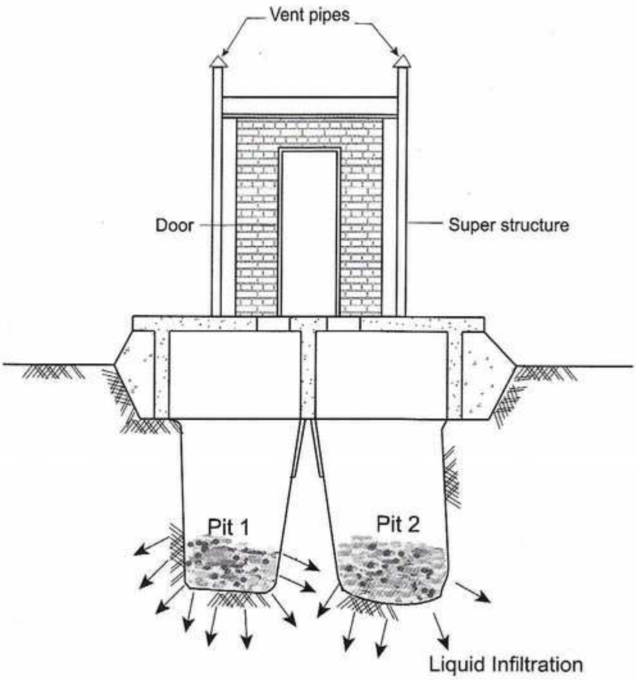

Figure 9.3 Alternating twin-pit VIP latrine

Odour and insect control

The principal mechanism of ventilation in VIP latrines is the action of wind blowing across the top of the vent pipe. The wind creates a strong circulation of air through the superstructure, down through the squat hole, across the pit, and up and out of the vent pipe. Unpleasant faecal odours from the pit contents are thus sucked up and exhausted out of the vent pipe, leaving the superstructure odour-free.
Flies, searching for an egg-laying site, are attracted by faecal odours coming from the vent pipe, but they are prevented from entering by the flyscreen at the outlet of the vent pipe. Some flies may enter into the pit via the squat hole and lay their eggs there. When new adult flies emerge they instinctively fly towards light. However, if the latrine is dark inside the only light they can see is at the top of the vent pipe. Since the vent pipe is provided with a flyscreen at its top, flies will not be able to escape and eventually they will die and fall back into the pit.

To ensure that there is a flow of air through the latrine there must be adequate ventilation of the superstructure. This is usually achieved by leaving openings above and below the door, or by constructing a spiral wall without a door.

Design considerations for VIP latrines

Design Life: For single-pit VIP latrines, the design life should be as long as possible; at least 10 years is desirables. The longer the design life, the longer the interval between relocating or emptying the latrine. For alternating twin-pit VIP latrines the design life should be 1-3 years.

Dimensions: Usually the pit cross-sectional area should not be more than 2 m^2 in order to avoid cover slabs with large spans. In practice, VIP latrines serving one household commonly have a diameter of 1-1.5 m or, in case of square or rectangular pits, a width of 1-1.5 m.

Vent Pipe: Vent pipes of a wide variety of materials are used, for example, polyvinyl chloride (PVC), unplasticized PVC (uPVC), bricks, etc. Whatever material is used, its durability (including corrosion resistance), availability, cost and ease of construction are important factors. The vent pipe should be sufficiently long so that the roof does not interfere with the action of wind across the top of the vent pipe. For flat roofs, top of the vent pipe should be at least 500 mm higher than the roof, and in case of sloping roofs the vent pipe should be 500 mm above the highest point of the roof.

The internal diameter of the vent pipe depends on the required venting velocity necessary to achieve the recommended ventilation rate of 20 m^3/hr. This in turn depends on factors like internal surface roughness of the pipe, its length (which determines the friction losses), the head loss through the flyscreen and wind direction. Current recommendations for minimum internal size of vent pipes are as follows:

PVC	150 mm diameter
Brick	230 mm square
Others	230 mm diameter

Flyscreen specification: The purpose of the flyscreen is to prevent passage of flies and mosquitoes; therefore, the mesh aperture must not be larger than 1.2 mm x 1.5 mm. The flyscreen must be made of corrosion-resistant material that is able to withstand intense rainfall, high temperatures and strong sunlight. It is preferable to use stainless steel screens.

Relocation and emptying of pits

When single-pit VIP latrines become full, there are two options: i) construction of a new latrine on an adjacent site, or ii) emptying the existing pit. In rural areas, construction of a new latrine, reusing the slab and vent pipe from the old one is preferred if space is available. Otherwise manual emptying is required which might pose health risks due to pathogens present in the fresh faecal material at top of the pit. A better solution might be to use single-pit VIP latrines with soakage or alternating twin-pit VIP latrines.

No health risk is expected from manual removal of the humus-like material from the pit of an alternating twin-pit VIP latrine which is at least two years old, as all the excreted pathogens are non-viable, except a few Ascaries ova.

Soakaway

A VIP latrine with adjacent soakaway increases the pit life. The latrine pit is completely sealed with cement mortar or mortared brickwork and a PVC pipe of 75mm dia which leads to the adjacent soakaway is attached at a height of about 2.25m above the pit base.

The soakaway has a diameter of 1.5 m and a depth of 2m. It is lined with unmortared bricks to a depth of 1.4 m. At this depth a reinforced concrete cover slab is placed on the bricks and the remaining space above it is backfilled.

Advantages and disadvantages

The major advantages of VIP latrine technology are as follows:
- controls odour and insects;
- minimum health risk;
- low cost;
- easy construction and maintenance;
- minimum water requirement;
- twin-pit VIP latrine system offers a long-term solution.

The main disadvantages of a VIP option may be as follows:
- potential for groundwater pollution;
- lack of space for relocating the pit in densely populated areas;

- difficulty of construction in rocky and high water table areas.

9.4 REED ODOURLESS EARTH CLOSET (ROEC)

The Reed odourless earth closet (ROEC) is a variation on the ventilated improved pit latrine. With ROEC, the pit is fully off-set from the superstructure and is connected to the squatting plate by a curved chute as shown in Figure 9.4.

The ROEC is fitted with a vent pipe to control odour and insect nuisance. It is claimed that the chute, in conjunction with the ventilation stack, encourages vigorous air circulation down the latrine, thereby removing odours and discouraging flies. This latrine is common in southern Africa. The design considerations and design principles of ROEC are similar to those of a single pit VIP latrine.

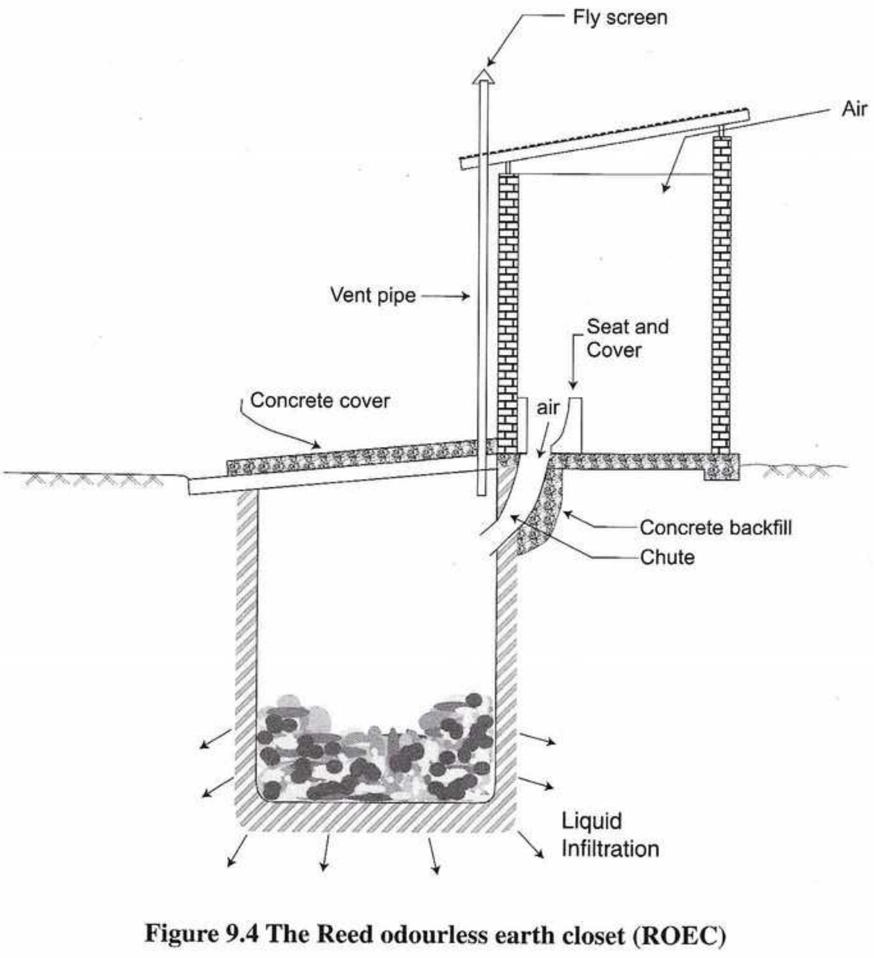

Figure 9.4 The Reed odourless earth closet (ROEC)

Advantages and Disadvantages of ROEC

The important advantages of ROECs are as follows:

- ROEC pit can be made larger as the superstructure is fully off-set and thus can have a longer life than VIP latrine;
- pit can be easily emptied without disturbing the superstructure and it can be a permanent facility;
- there is no danger of users, particularly children, falling into it;
- it may be more acceptable to users because the excreta cannot be seen.

The main disadvantages are as follows:

- the ROEC chute easily becomes fouled with excreta, thereby providing a possible site for fly breeding and odour nuisance;
- the chute has to be regularly cleaned with a long-handled brush or a small amount of water.

9.5 COMPOST LATRINES

The basic principle of a compost latrine is that aerobic decomposition of faeces generates sufficient heat to destroy the pathogens and forms a good soil conditioner/ fertilizer for subsequent use. Necessary conditions for the compost process include an appropriate carbon to nitrogen (C/N) ratio, a low moisture content and access to air to ensure aerobic conditions.

Household systems for composting excreta and other organic materials are used under a variety of conditions. They are successful in both developing and industrialized countries where there is a tradition of using human excreta on the land, and receive intensive attention from the users. This type of latrine will be sustainable in the areas where there is an urgent need for fertilizer or when there is high degree of environmental concern.

There are two types of compost latrines with variations in details:

- continuous compost latrine
- batch compost latrine

Continuous compost latrine

Continuous compost latrines ('Multrum' type) are extremely sensitive to the degree of user care because the humus has to be removed at the correct rate, organic matter has to be added in correct quantities, and only a minimum of liquid can be used. Human excreta and vegetable wastes are added to a receptacle (Figure 9.5) which is commonly made of fibreglass (e.g., in Sweden, the United States and Canada).

For good operation about eight times as much vegetable waste as faeces is added to give a suitable C/N ratio of about 30 (Pickford, 1995). The mixture of excreta and vegetable matter slides down a sloping floor and is removed from a storage chamber.

The material is kept aerobic by ducts and may remain in the receptacle for several years. Originally a Swedish design, the Multrum has been strongly supported for environmental reasons in the developed countries. However, experience in developing countries including those in Africa, Asia and Latin America were not successful. Common problems encountered were that the mixture of excreta and vegetable matter was too wet, and that insufficient vegetable matter was added, especially during the dry season.

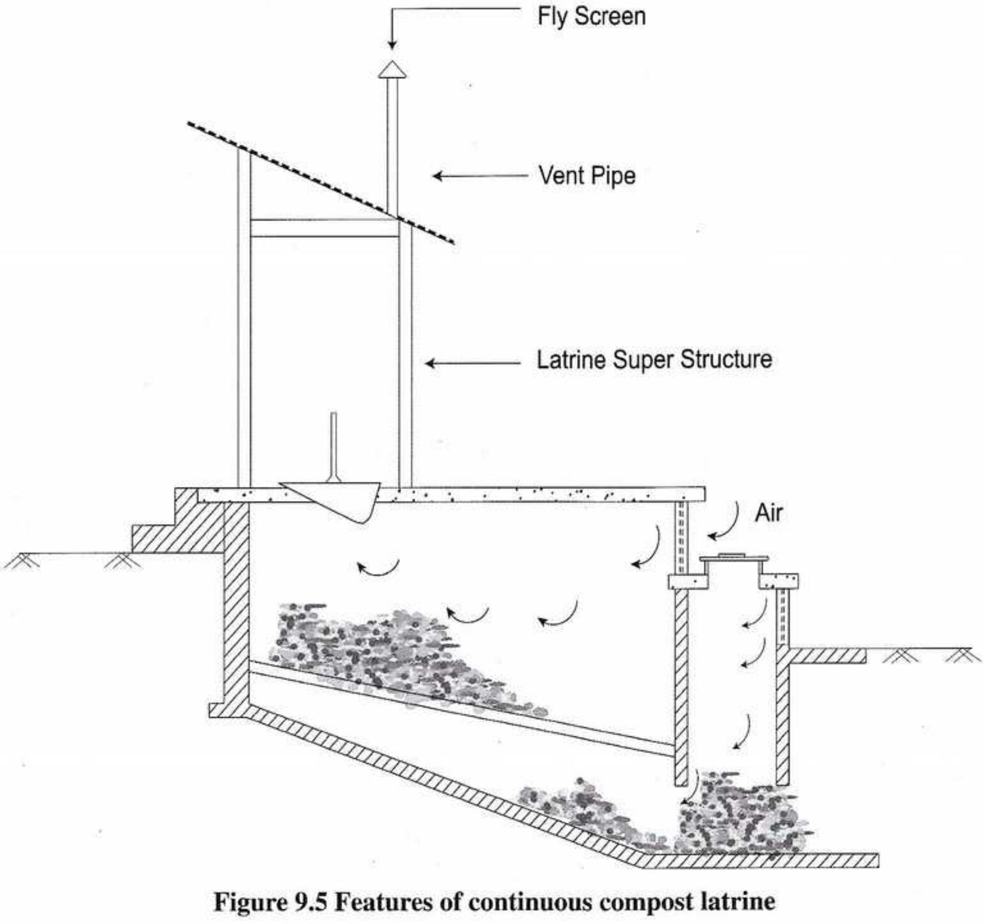

Figure 9.5 Features of continuous compost latrine

Batch compost latrine

The most common type of compost latrine is the batch or double vault system (Figure 9.6). It has two watertight chambers or vaults used alternately which may be constructed either above or below ground and may have sealed or impermeable bases. One vault is used until nearly full and the remaining space is filled with dry soil or organic matter, such as leaves or grass, and then it is sealed while the second vault is used.

The vaults are usually designed to take at least one year to fill. Fillers are added to provide carbon to achieve suitable C/N ratio.Without enough filler some nitrogen in compost latrines is lost and the resulting compost is less valuable as a fertilizer. Ash, vegetable matter, soybean leaves, sawdust, waste paper and shredded leaves are found to be suitable as fillers in compost latrines.

Ash controls odours and helps keep the mixture fairly dry in addition to providing carbon to maintain a suitable C/N ratio. Urine is collected separately to reduce nitrogen and moisture levels in the compost pile. For the same reason water should not be added to the pile. The humus thus produced by a compost latrine that is functioning well will be a dark and inoffensive material which can be applied to fields as fertilizer.

In Vietnam the floor of the vaults was made above ground level to exclude surface water. Before the vault (in Vietnam the word 'bin' is used for vault, emphasizing the need to keep the contents dry) was used a layer of ashes or lime was put at the bottom to absorb liquid and prevent faeces sticking to the floor. To control odour ashes weighing about a third of the weight of faeces were added. The temperature rose only a few degrees above ambient but most helminths were reported to be killed in about eight weeks. When these latrines were built and used by everyone, there was up to 85 % reduction in diarrhoea and 50 % reduction in worm infections and when compost was applied to fields the crop yield increased by up to 70 % (Pickford, 1995).

Advantages and disadvantages

The following are the major advantages of compost latrines:

- appropriate for use in areas where there is a tradition of using human excreta on the land.
- can be useful in areas where there is a need for soil conditioner.
- need no water for flushing because composting is most efficient if the material is moist but not wet; need not penetrate the subsoil and can be built on rock, pose a low pollution risk, particulrly if they are completely sealed units and they can be used to prevent contamination of a vulnerable water supply.

The disadvantages of compost latrines can be mentioned as follows:

- need organic waste to correct the C/N ratio of the excreta and a substantial amount of biodegradable organic matters must be locally available.
- need care in their operation, and should be applied where users are keen to operate the system carefully to obtain compost for fields or gardens.

- this type of latrine is not very suitable for areas where people prefer water for anal cleansing.
- if correct measures are not taken, the contents of the latrine can easily become too wet and fly breeding will result.
- if the wastes are not stored for a long enough period of time, pathogenic organisms will persist in the compost, resulting in health risks.

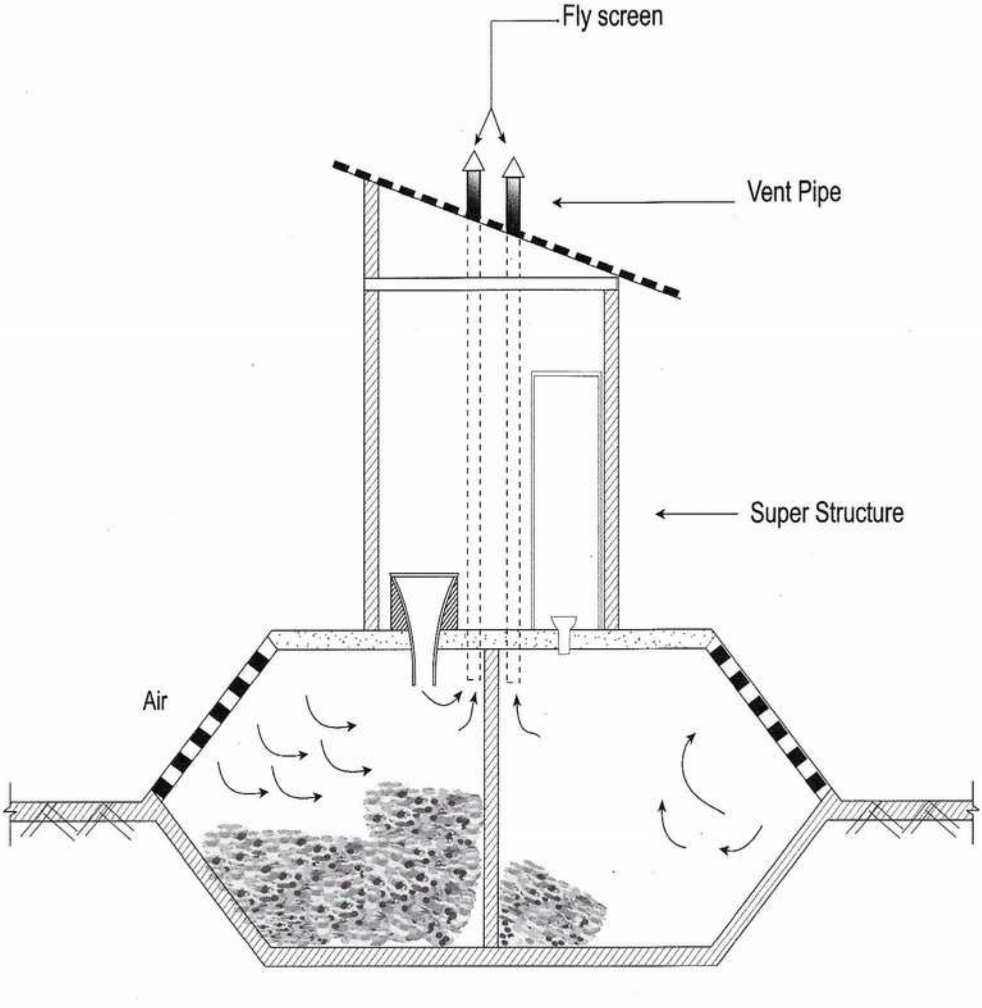

Figure 9.6 Double vault compost latrine

9.6 POUR-FLUSH SANITATION TECHNOLOGIES

Pour-flush technology is a further improvement to the simple pit latrine in that it offers better odour and insect control by a water seal and is widely accepted as a low-cost sanitation alternative. The most vital part of the pour-flush (PF) sanitary latrine is the water seal incorporated between the squatting plate or seat and the pit, which essentially prevents unpleasant odours and insects from entering the latrine compartment. The pour-flush latrine has three major component parts: (a) the superstructure, (b) the latrine pan with its integral waterseal, and (c) a single or alternating twin leach pits. There are two basic types of pour-flush latrines.

- direct pit pour-flush latrine
- off-set pit pour-flush latrine

Direct pit pour-flush latrine

The first is a modification of the simple pit latrine in which the squatting plate is provided with a 25 mm water seal and is placed directly over the pit. This type (Figure 9.7) can be termed as a 'direct pit pour-flush' latrine.

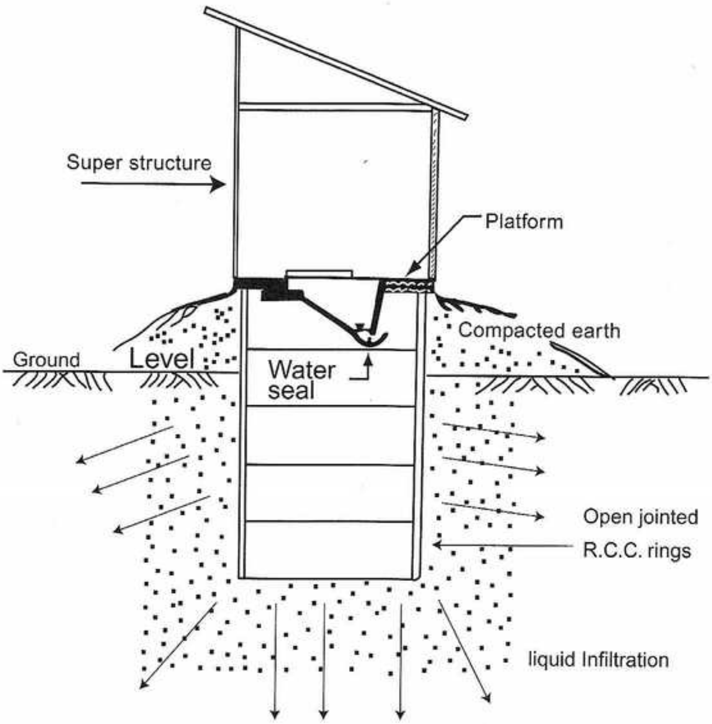

Figure 9.7 The direct pit pour-flush latrine

Off-set pit pour flush latrine

The second type has a completely off-set pit connected to the pour-flush pan by a short length of 100 mm diameter pipe. This type can be termed an 'off-set pit pour-flush' latrine which can even be installed inside the house, as it is free from faecal odour and insect problems, thus avoiding the need for a separate superstructure. This can further be classified as 'single off-set pit pour-flush' latrine (Figure 9.8) and 'alternating twin off-set pit pour-flush' latrine (Figure 9.9).

Alternating twin off-set pit pour-flush latrine

The alternating twin-pit system comprises (a) a squatting pan, (b) two leach pits, and (c) a Y-junction for directing excreta from squatting pan to either of the two leach pits. The pits are used alternately and at any given time only one pit is in use. When the first pit is full, the flow of excreta is directed to the second pit through a Y-junction and contents of the first pit is left to decompose. The contents of the first pit decomposes to safe, pathogen-free humus within 18 to 24 months. The contents of the first pit may then be dug out and the pit is kept ready for reuse.

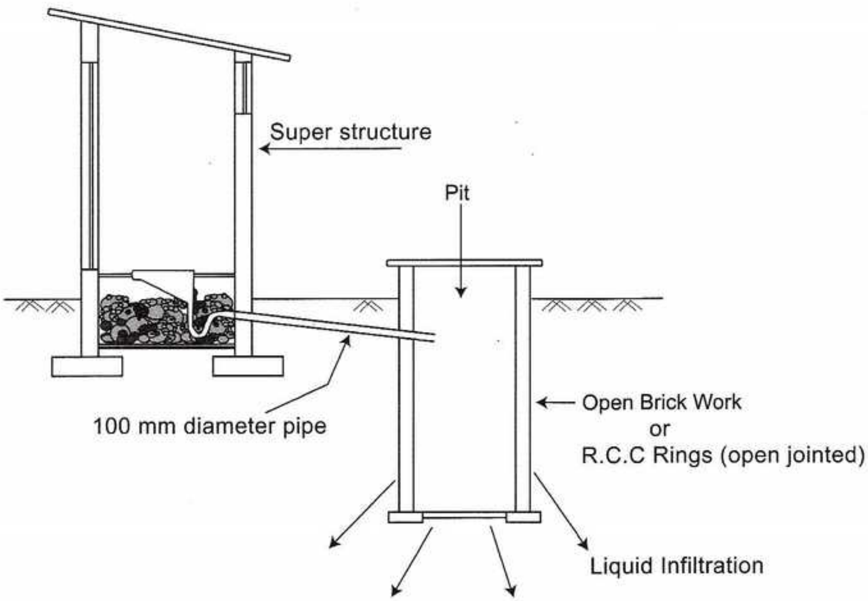

Figure 9.8 Single off-set pit pour-flush latrine

Functions of pour-flush latrines

The basic functions of a pour-flush latrine are:

- After each use, the latrine is manually pour-flushed through the pan and trap with about 2-3 litres of water. Some of the clean flushwater remains in the trap and maintains the water seal, thus providing the barrier against odours and insects as in the case of conventional cistern-flush toilets which use between 10 and 20 litres of water per flush.

- From excreta and flushwater around 5-10 litres per capita per day (lcd) of wastewater enter the pit, together with an additional usually equal amount if water is used for anal cleansing. The pit has to provide sufficient volume for solids storage, as well as sufficient area for the wastewater to infiltrate into the soil, which requires that the soil has sufficient long-term infiltrative capacity. If the soil is unsuitable for infiltration, the liquid effluent can be removed by other means e.g., by connecting to the sewerage system if available.

Suitability of pour-flush latrine types

Pour-flush latrines may be used in both rural and urban areas provided they are appropriately designed and that they can rely on water availability for flushing, and for maintaining the water seal. Single pits may be appropriate in urban areas only if they can be desludged mechanically by a vacuum tanker, since their contents are not pathogen free. Twin-pits are recommended if the pits are to be desludged manually, as the resting period ensures that the contents to be removed are substantially free of excreted pathogens.

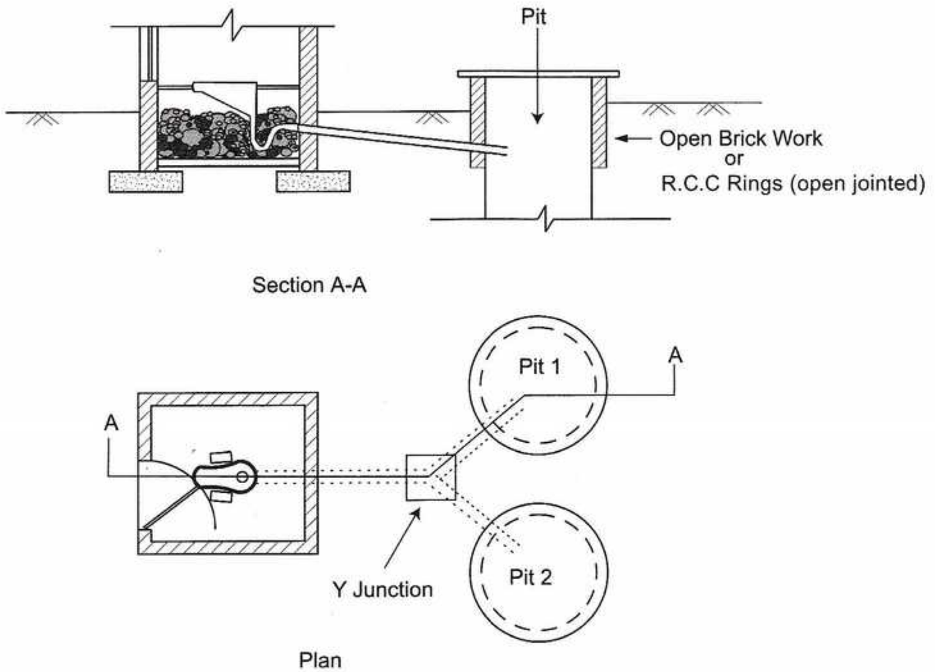

Figure 9.9 Alternative twin off-set pour-flush latrine

In rural areas mechanical desludging is neither reliable nor affordable. Consequently, pits should be designed for manual desludging. In rural areas of Bangladesh, single direct pit pour-flush latrines are extensively used as they are very cheap to construct. When the pit is full, a new pit can be dug and the superstructure, and the squatting slab including the water seal pan can be placed over the new pit. The filled-up pit can be covered with some soil and left for a sufficient period of time before it can be emptied again for reuse.

Alternating twin off-set pit pour-flush latrines offer a much better solution if they can be afforded. If twin-pits cannot be afforded during the initial construction, the pipe layout and the first pit can be so placed so as to allow for the installation of a second pit when the first becomes full. For alternating twin off-set pit latrines, it is also possible to have a variety of arrangements of the pits (Figure 9.10) to suit local space conditions.

Design considerations for pour-flush latrines

Several things should be taken into consideration when designing pour-flush latrines.

- The shape of pits can be circular, square, rectangular or even triangular depending on shape and size of the site.
- The minimum water requirement is 2-3 litres for flushing the toilet by hand.
- For ease in emptying and avoiding the possibility of groundwater pollution it is desirable that the pits are shallow in depth where the groundwater table is high. In most areas in Bangladesh, pits should not exceed 1.8 metres.
- Pits may be lined with burnt clay, concrete, brick masonry, or even bamboo. About 0.60 metres below the top of pit, honeycomb bricks with horizontal open brick joints should be provided.
- The inlet into the pit should be at least 0.5 metres above the highest ground water level.
- A free space should be kept over inlet of the pit. In practice, 0.5 metres of free space at the top of the pit is usually kept above the inlet.
- In low-lying or flood-prone areas, the pits should be constructed on elevated earthen mounds with at least 1.50 metres earth covering all around the pits.
- Bottom of pit should remain undisturbed and unsealed and if it is 2.0 metres above the water table.
- Safe distance between pits and tubewells or any other waterbodies should be at least 10.0 metres.
- The infiltration capacity of soil is important for proper functioning of the pit latrines. Sandy or silty soil with/without clay is considered ideal. For pits in compacted clayey soil of low permeability, such as in the Barind Tract, a sand envelope of at least 0.3 metres should be provided around the pits.
- The distance between two pits should be at least equal to the effective depth of the pits, which is measured from the inlet pipe to bottom of the pit.

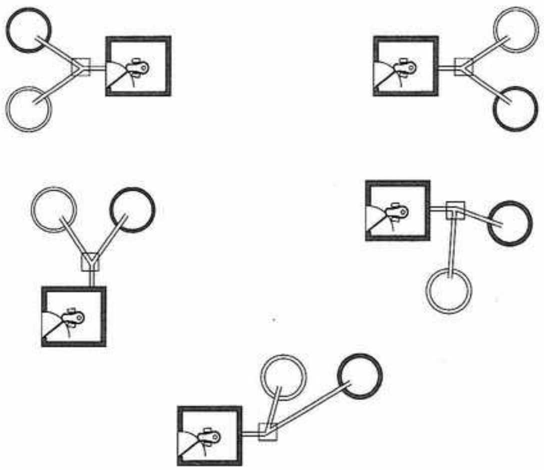

Figure 9.10 Different pit arrangements for twin off-set pit latrines

Design of pour-flush leach pits

Leach pits for pour-flush latrines have to be designed for storage and digestion of excreted solids as well as infiltration of the liquid waste into the surrounding soil. Designing for storage and digestion of solids is exactly the same as for other pit latrines e.g., the VIP latrines using equation 9.1. Infiltration of the liquid effluent, however, requires that sufficient pit-soil interface area is available depending on the long-term infiltration capacity of the soil.

Pit effluent enters the soil first by infiltrating the pit-soil interface, which is partially covered in a bacterial slime layer, and then by percolating away through the surrounding soil. Mara (1996) suggests that simple percolation tests, which measure how quickly clean water passes through undisturbed soil, should not be used to measure infiltration of pit effluent. The long-term infiltration rate depends on the type of soil and suitable design values are given in Table 9.2.

Table 9.2 Design values for long-term infiltration rates for wastewater into various soils

Soil type	Long-term infiltration rate (l/m^2 day)
Sand	50
Sandy loam	30
Porous silty loam, porous silty clay loam	20
Compact silty loam, clay	10

(Source: Mara, 1996)

The side wall area required for infiltration, (A_i, m^2) depends on the wastewater flow (Q, l/day) and the long-term infiltration rate according to the following relationship:

$$A_i = Q / I \qquad (9.3)$$

The wastewater flow depends on the number of users, frequency of flushing, flush volume, urine volumes and amount of water used for anal cleansing. Generally the flow varies between 5-20 lcd.

The pit volume, V_i (m^3) corresponding to the sidewall area can now be calculated. For a circular pit of diameter, D,

$$V_i = \pi D^2 h/4 \qquad (9.4)$$

where h, the height of the sidewall area = $A_i / \pi D$

$$\therefore \quad V_i = A_i D/4$$

$$\text{i.e.,} \quad V_i = QD/4I \qquad (9.5)$$

For alternating twin-pits, the effective volume of each pit is calculated either using equation (9.5), or equation (9.1) i.e., $V_s = C \times P \times N$, whichever is greater.

For single pit pour-flush latrines, the effective volume is given by:

$$V = V_s + V_i \qquad (9.6)$$

This estimate however, is slightly conservative as some infiltration would also occur through the side wall area corresponding to V_s. But this better allows restoration of the infiltrative capacity after emptying. In case of alternating twin-pits this restoration occurs during the rest period.

Advantages and disadvantages of pour-flush technology

The main advantages of pour-flush technologies are listed below:

- Less expensive compared to conventional latrines (with sewerage systems)
- Offer appropriate and hygienic solution for excreta disposal
- Require low volumes of water for flushing, (2-3 litres/flush only)
- Can be upgraded to connect to a sewer system or septic tank system
- Eliminate odours, insect and fly breeding
- Safe for children
- Can be located, if desired, inside the house
- Potential for resource recovery using the sludge as soil conditioner
- Easy construction and maintenance of single pit pour-flush latrine

The disadvantages are as follows:

- Require separate sullage disposal facilities.
- Water (at least 5 litres/person/day) must be available throughout the year
- Water seal may be clogged easily if garbage is thrown into it
- Construction is difficult and expensive in areas with high groundwater and shallow soil overlying hard rock
- Risk of polluting nearby water sources

Prevention of groundwater pollution

The liquid effluent from leach pits of different types of pit latrines will infiltrate both laterally and vertically into the soil and through to the groundwater if the aquifer is an unconfined one. If the leach pit bottom is close to the groundwater table (Figure 9.11), then bacteria or other contaminants may travel both downwards and laterally, transported by the groundwater. The lateral movement will always be in the same direction as the flow of the groundwater. It is therefore important that latrine locations are carefully selected with respect to sources of water supply, to avoid the risk of pollution.

It has been indicated (Mara, 1996) that if there are at least 2.0 metres between the pit bottom and the groundwater table, little microbial pollutant travel occurs in most unconsolidated soils and a horizontal distance of 10.0 metres between a drinking water well and a latrine is often satisfactory.

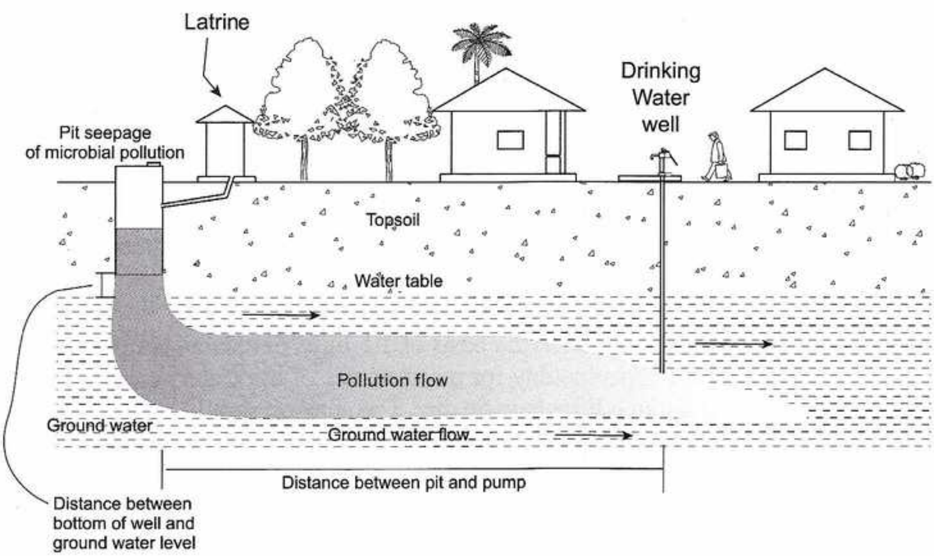

Figure 9.11 Groundwater pollution from pit latrines (after Dahi, 1996)

If, however, there is a serious risk that the local aquifer, which is used as a source for public water supply, may be polluted from the pit leachate, it is suggested that the pit base should be sealed with lean concrete and a 0.5 m annulus of sand placed between the pit lining and the soil. The effective size of the sand should be less than 1.0 mm. This will considerably reduce the contaminant travel into the groundwater. Regular monitoring of nitrate concentration in wells can provide an indication of groundwater contamination by pathogens.

9.7 AQUA PRIVIES

An aqua privy consists of a squatting plate or seat with superstructure above a small septic tank that discharges its effluent to an adjacent drainage field or a soak pit (Figure 9.12). The squatting plate has an integral drop pipe which is submerged into the water of the tank to form a water seal. Excreta are deposited directly into the tank without the need for flushing, where they settle and are decomposed anaerobically. The solids accumulate and have to be removed regularly.

Maintenance of the water seal is the most important aspect of aqua privies and this has always been a problem, except in communities where water used for anal cleansing has been sufficient to maintain the seal. Failure to maintain the water seal results in intense odour release and fly and mosquito nuisance. The large number of failures of conventional aqua privies usually occur due to negligence.

To overcome the problem of losing the water seal a variation in the conventional design is often made. In this modification, the tank consists of two interconnected compartments, of which one is used to collect all household sullage in order to keep the water level high, thus ensuring that the water seal is maintained. However, the additional water passing through the tank would require larger adsorption field or larger soak pits.

The aqua privy has no technical advantage over the pour-flush latrines, which are easier to build maintain and cost less, particularly in areas where water is used for anal cleansing. Thus, aqua privy systems ordinarily cannot be recommended as a viable sanitation option since they can be replaced by technically superior options at a lower cost.

The tank volume is usually calculated on the basis of 1.5 litres of excreta per person per day plus an additional 4.5 litres/person/day for maintenance of the water seal. Thus, the aqua privy effluent flow is about 6 litres/person day. The soak pit should be designed on this basis, although it is common practice to include a factor of safety so that the design flow would be about 8 litres/person day. The side wall area of the soak pit should be calculated assuming an infiltration rate of 10 litres/m^2/day. For septic tanks, there is an accumulation of sludge 0.03-0.04 m^3/person/year, which should be removed when the tank is 2/3 full. As a result, the desludging process is normally carried out every 2-3 years. The liquid depth in the tank is normally 1 to 1.5 metres in household units.

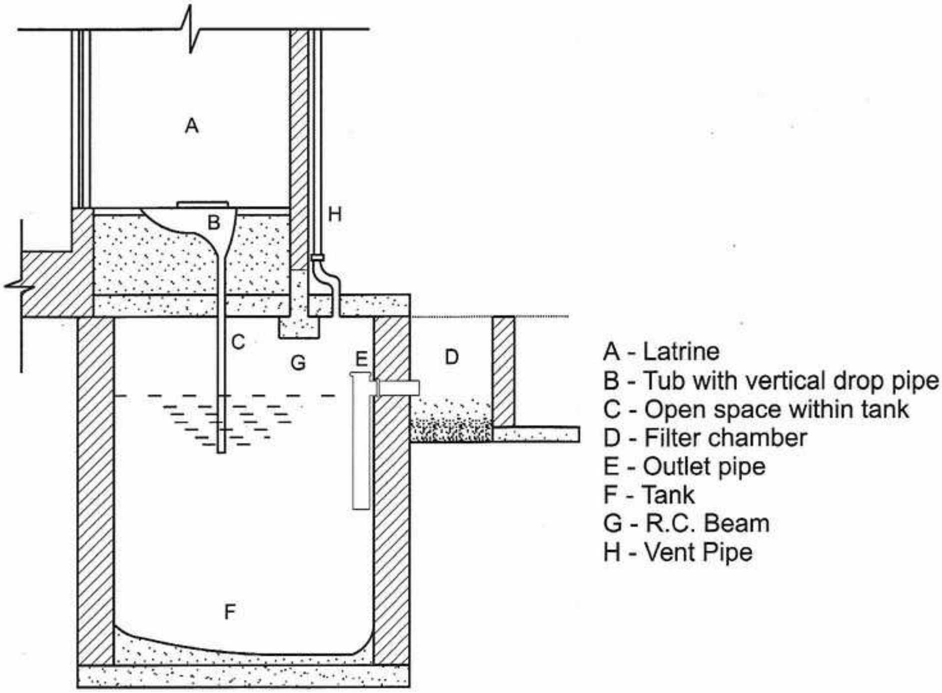

Figure 9.12 Conventional aqua privy

Advantages and disadvantages

The advantages of a conventional aqua privy are listed below:

- low odour and insect problems, provided the water seal is maintained;
- minimal risks to health;
- low annual costs;
- potentials for upgrading;
- sullage disposal potential.

The disadvantages are as follows:

- difficulties in maintaining the water level and hence the water seal;
- higher investment costs compared to pour-flush or VIP latrines;
- cannot be installed within the house;
- tanks needed to be water tight;
- additional water required for maintaining the water level;
- desludging is required on a regular basis by local municipal authorities.

9.8 SEPTIC TANK SYSTEM

A septic tank is a buried, watertight receptacle designed and constructed to receive wastewater from a home, to separate the solids from the liquid, to provide limited digestion of organic matter, to store solids, and to allow the clarified liquid to discharge for further treatment and disposal (Polprasert et. al., 1982). Settleable solids and partially decomposed sludge settle to the bottom of the tank and gradually build up. A scum of light-weight material including fats and greases rises to the top. The partially treated effluent is allowed to flow through an outlet structure just below the floating scum layer. This partially decomposed liquid can be disposed of through soil absorption systems, soil mounds, evaporation beds or anaerobic filters depending upon the site conditions. The essential components of a septic tank system are shown in Figure 9.13.

Processes in a septic tank

Although a septic tank is simply a sedimentation basin with no external or internal moving parts or added chemicals, the natural processes that take place within the tank are complex, and interact with each other. The most important processes that take place within the tank include separation of suspended solids, digestion of sludge and scum, stabilization of the liquid, and growth of micro-organisms.

Separation of suspended solids is a mechanical process which results in the formation of three distinct layers in the septic tank - a layer of sludge at the bottom, a floating layer of scum on the top and a relatively clear layer of liquid in the middle.

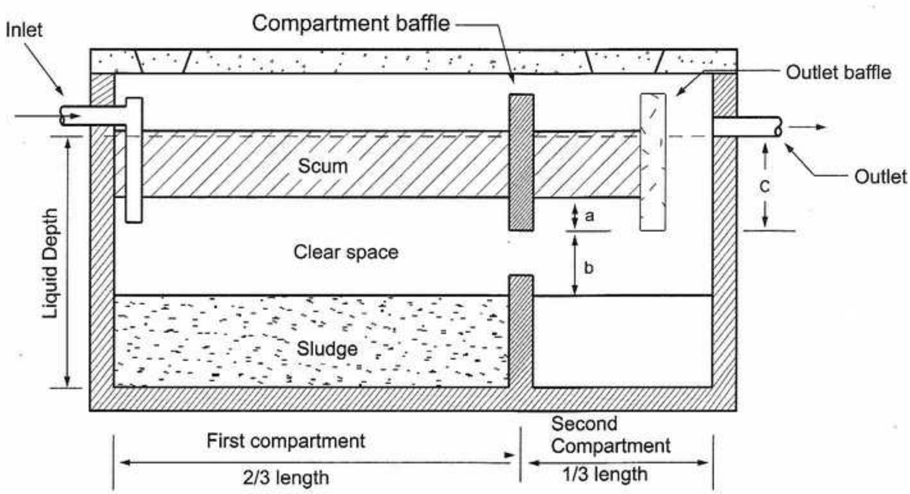

Figure 9.13 Components of a septic tank system

Anaerobic bacteria degrade the organic matter in the sludge as well as in the scum and as a result of this bacterial action, volatile acids are formed at the first instance and eventually are converted mostly to water, carbon dioxide and methane. The formation of gases in the sludge layer causes irregular floatation of sludge flocs that resettle after the release of the gas at the surface.

Organic materials in the liquid are also stabilized by anaerobic bacteria, which break down complex substances into simpler ones in a process similar to the one that take place in the sludge layer.

A large variety of micro-organisms grow, reproduce and die during the biodegradation processes that take place in the tank. Most of them are attached to organic matter and are separated out with the solids. Although there is an overall reduction in the number of micro-organisms, a large number of bacteria, viruses, protozoa and helminths survive the processes in the tank and remains active in the effluent, the sludge and the scum.

Performance of a septic tank

The performance of a septic tank greatly depends on its design. A properly designed septic tank performs efficiently in the removal of settleable matter and the biochemical oxygen demand (BOD). However, the effluent from a septic tank still contains high concentrations of BOD, pathogens, nitrogen and phosphorous, which prohibits its discharge into any water course or on land without further treatment.

Under normal design conditions, reduction in BOD of 25 - 50% and in suspended solids (SS) of up to 70% have been reported in literature. The high reduction in BOD and SS can however, be obtained by prolonging the retention time, which in most cases may not be practicable.

Apart from the retention time, the other factors which affect the performance of the septic tank are:

- ambient temperature;
- the nature of the influent wastewater;
- its organic content;
- the positions of the inlet and outlet devices in the tank.

The digestion of the sludge and scum depends on the microbial population and the temperature. Sludge and scum decompose more slowly at lower temperatures and are accelerated by an increase in temperature.

Design procedure

The septic tank design procedure presented here,is based on the Brazilian septic tank code, which takes a more rational approach to design than others. In this approach, the tank is considered to be made up of four zones, as shown in Figure 9.14, each of which serves a different function:

- scum storage zone

- sedimentation zone
- sludge digestion zone
- digested sludge storage zone

Scum storage: Scum accumulates at approximately 30-40 % of the rate at which sludge accumulates, so the tank volume for scum storage (V_{sc}) can be taken as 0.4 times the volume for sludge storage (V_{sl}),

i.e., $$V_{sc} = 0.4\, V_{sl} \tag{9.7}$$

Sedimentation: The time required to allow sedimentation of settleable solids decreases with the number of people served according to the following equation:

$$t_h = 1.5 - 0.3 \log (Pq) \tag{9.8}$$

where t_h = minimum mean hydraulic retention time for sedimentation, days
P = contributing population
q = wastewater flow per person, l/day.

Retention times in septic tanks are longer than those normally employed in raw sewage sedimentation tanks. This is because of the fact that septic tanks are required to intercept solid that enter the tanks with waste inflow as well as solids, which rise up from the sludge layers through flotation by the gases produced due to anaerobic digestion. Often a minimum mean hydraulic retention time of one day is used. The value of t_h used should not be less than 0.2 days.

The tank volume for sedimentation, V_h (m^3) is given by:

$$V_h = 10^{-3}\, P\, q\, t_h \tag{9.9}$$

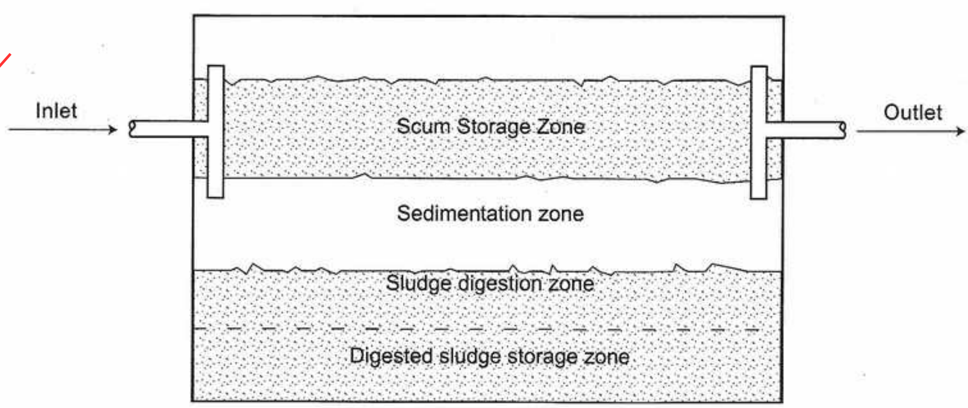

Figure 9.14 Functional zones in a septic tank

Digestion: The time needed for the anaerobic digestion of the settled solids (t_d, days) varies with temperature (T, °C) and is given by the equation:

$$t_d = 1853\ T^{-1.25} \tag{9.10}$$

Alternatively, the value of t_d can be obtained by considering the process growth kinetics of a completely mixed anaerobic digester (Mara 1996).

The minimum retention time for the anaerobic biomass (θ_{min}, days) depends on how fast the bacteria can utilize their food supply, and on how much food is needed to generate additional biomass. If food is taken to be organic matter, or BOD, then:

$$\theta_{min} = 1/Y\,k_T \tag{9.11}$$

where Y = yield coefficient, mg cells produced per mg BOD utilized
k_T = maximum BOD utilization rate, per day.

The value of Y is around 0.04 for high lipid wastes. In the temperature range 20-35 °C, k_T varies with temperature as follows:

$$k_T = 6.67\ (1.035)^{T-35} \tag{9.12}$$

Combining equation (9.11) and (9.12) with $Y = 0.04$, gives:

$$\theta_{min} = 3.75\ (1.035)^{35-T} \tag{9.13}$$

However, it is necessary that a large factor of safety be applied to equation 9.13 to allow for the difference between a well-controlled anaerobic reactor and a septic tank (which is basically uncontrolled by comparison), so that t_d is given by:

$$t_d = 30\ (1.035)^{35-T} \tag{9.14}$$

The volume of fresh sludge is around 1.0 litre/person/day. This is digested in t_d days when it passes to the sludge storage zone. So the average volume of digesting sludge present during the period t_d is 0.5 lcd. Thus the volume of the sludge digestion zone, V_d (m^3), is given by:

$$V_d = 0.5 \times 10^{-3}\ P\ t_d \tag{9.15}$$

Sludge storage: The volume of the sludge storage zone depends on the rate of accumulation of digested sludge (C, m^3 per person per year) and the interval between successive desludging operations (N years). Design values for sludge accumulation rates are taken as:

$C = 0.06\ m^3$/person year   for $N < 5$

$C = 0.04$ m³/person year for $N > 5$

The sludge storage volume, V_{sl} (in m³) is given by:

$$V_{sl} = C \times P \times N \tag{9.16}$$

Overall design capacity: The overall design capacity of the septic tank is the sum of the volumes required for scum storage, sedimentation, digestion and sludge storage, i.e., the total septic tank volume:

$$V = V_{sc} + V_h + V_d + V_{sl} \tag{9.17}$$

Since V_{sc} is about 0.4 V_{sl}, equation (9.17) becomes:

$$V = V_h + V_d + 1.4\, V_{sl} \tag{9.18}$$

Clear space depth: The clear space depth, which is the minimum acceptable depth of the sedimentation zone just prior to desludging, comprises the submerged scum clear depth and the sludge clear depth.

The submerged scum clear depth is the distance between the underside of the scum layer and the bottom of the outlet 'tee', and should be at least 75 mm.

The sludge clear depth is the distance between the top of the sludge layer and the bottom of the outlet 'tee'.

The minimum value of the sludge clear depth is related to the tank surface area, A, as follows:

$$d_{sc} = 0.82 - 0.26\, A \tag{9.19}$$

subject to a minimum value of 0.3 m.

Thus the minimum total clear space calculated as $(0.075 + d_{sc})$ must be compared with the depth required for sedimentation, i.e., (V_h / A), and the greater depth chosen.

Shape and dimensions of the tank

The shape of the tank influences the velocity of wastewater flowing through the tank as well as the depth of sludge accumulation. If the tank is too deep then the other dimensions will be too small, which might result in short-circuiting of the inlet and outlet flow, thereby shortening the detention time. Conversely, if the tank is too shallow, the clear space depth will be too small for the detention of the settleable solids. However, tanks with greater surface area and of reasonable depth are preferred, because increased liquid surface area increases surge storage capacity. These surges of flow through the tank diminish as the surface area increases.

A rectangular septic tank has been reported to be better than a square septic tank, while long narrow tanks are more satisfactory. Tanks of cylindrical shape of appropriate size are also reported to be satisfactory in some cases, and are less costly to install. However, a rectangular shape for a single compartment tank is most favoured with a length three times its width.

Compartmentation

A single compartment tank usually provides acceptable performance but a two-compartment tank is reported to be better than a single compartment tank of equal capacity for the removal of BOD, suspended solids and organic colloids. One of the reasons for this is the trapping action of the second compartment. A well-designed two compartment septic tank, the first compartment immediately after the inlet being two third of the total length, can effectively reduce discharge of solids with the tank effluent. It is reported that the benefit of dividing a septic tank into more than two compartments is insignificant.

Inlet and outlet devices

The design and position of inlet and outlet devices have considerable influence on tank operation. Wastewater should enter the septic tank without causing much disturbance to the sedimentation process and the outflow of a septic tank should carry only minimal concentration of settleable solids.

The inlet to a septic tank should be designed to dissipate the energy of the incoming water, to minimize turbulence and to prevent short-circuiting. The inlet should preferably be either a sanitary tee, an elbow, or a specially designed inlet device. The invert radius in a tee helps dissipate energy in the transition from horizontal to vertical flow. The vertical leg of the inlet tee should extend below the liquid surface, which minimizes induced turbulence by dissipating as much energy in the inlet as possible.

In order to limit the action of surge flows from flushing water closets and unplugged baths and sinks, the pipe to the septic tank should not be less than 100 mm in diameter, and the gradient not steeper than 1.5% for at least 10 metres. The inlet tee junction diameter should not be less than the diameter of the inlet pipe, the top limb should rise at least 150 mm above the water level, and the bottom limb should extend about 450 mm below the water level.

The ability of the outlet device to retain sludge and scum in a septic tank is a major factor in overall tank performance. The outlet of a septic tank is usually made with a tee junction. It should be placed in such a way that the bottom of the horizontal leg, i.e., the invert level, is below the level of the inlet pipe. As with the inlet tee junction, the vertical leg must extend beyond the top and the bottom of the scum layer so that the liquid can be discharged from the liquid zone between the scum and the sludge.

Construction methods and materials

The most important aspect of septic tank construction is that the tank should be installed on a level grade and at a depth that provides adequate gravity flow from the home and matches the invert elevation of the house sewer. The tank should be placed on firm ground so that settling is minimum. Tank performance can be impaired if a level position is not maintained because the inlet and outlet structures will not function properly.

Septic tanks must be watertight, structurally durable and stable. As a construction material, reinforced concrete adequately meets these requirements. Steel is another material that can be used for septic tanks but should be properly coated for corrosion resistance. Plastic and fibreglass tanks can also be used. These are very light, easily transported, and resistant to corrosion and decay. The walls of septic tanks should have a thickness of at least 80 to 100 mm and can also be made of brickwork. The important thing is that the tank should be made fully watertight.

The inlet and outlet pipes should be properly positioned and sealed with concrete or other adhering materials.

Disposal of septic tank effluents

As indicated earlier, the effluent from a septic tank is only partially treated and still contains high concentration of micro-organisms, BOD, phosphorous and nitrogen, which should not be discharged directly into a public water course or on land. Further treatment or other means of disposal are required. Where site conditions are suitable and do not pose any threat to groundwater quality, sub-surface soil absorption is usually the best method for septic tank effluent disposal.

The performance of the soil absorption systems depends on the ability of the soil to accept liquid, absorb viruses, strain out bacteria and filter the wastes. A proper site evaluation requires accurate measurement of the soil permeability, the degree of slope, the position of the water table and the soil depth. The following general guidelines can be considered for selecting soil absorption sites.

- Soil permeability should be moderate to rapid and the soil percolation rate should generally be 24 minutes per cm or less.
- The groundwater level during the wettest season should be at least 1.22 m (4 ft) below the bottom of the sub-surface absorption field or soak pit.
- Impervious layers should be more than 1.22 m below the seepage bed or the pit bottom.
- The site for an absorption field of a soak pit should not be within 15.24 m (50 ft) of a stream or other water body.
- A soil absorption system should never be installed in an area subject to frequent flooding.

Three different types of sub-surface soil absorption systems are commonly used: (a) absorption trenches, (b) absorption beds or seepage beds, and (c) absorption pits or soakage pits. The use of these types depends on the suitability of soil and other local conditions.

Absorption trenches: The effluent flows by gravity from the septic tank through a closed pipe and a distribution box into perforated pipes in trenches as shown in Figure 9.15. Usually the pipes consist of open-jointed drainage tiles of 10 cm diameter laid on a 1 m depth of crushed rocks or gravel and soil. Bacteria in the soil help purify the effluent.

The design of an absorption field can be done as follows:

$$L = \frac{Pq}{2DI} \qquad (9.20)$$

Where,

L = trench length (m)
P = number of users
q = wastewater flow (litres/capita/day)
D = effective depth of trench (m)
I = design infiltration rate (litres/m^2/day)

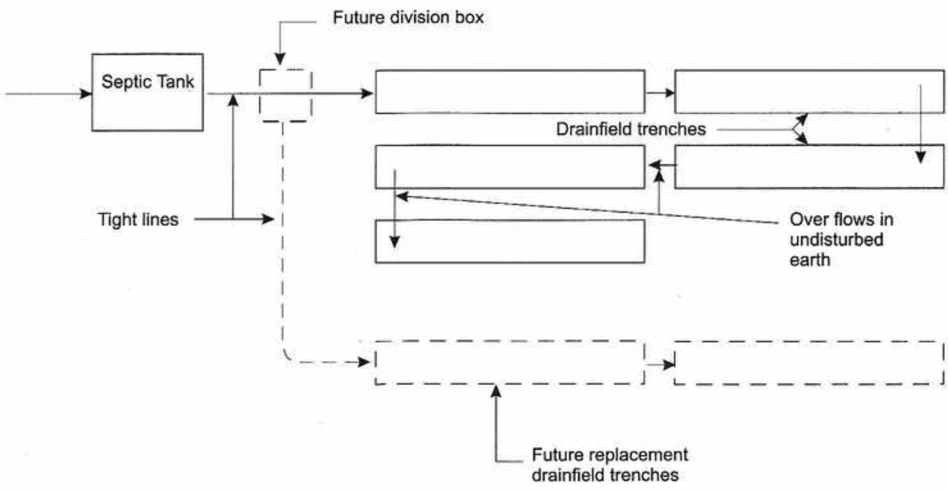

Figure 9.15 Sub-surface soil absorption trenches

Design infiltration rate for the septic tank is usually taken as 10 litres/m^2/day. The soil absorption system clogs up periodically, therefore overloading the system should be avoided in order to increase its operating life. Absorption fields must be located away from wells, streams, buildings and other objects. It is imperative that they be located downstream from utilized water sources.

Soakaways: These are deep excavations used for sub-surface disposal of septic tank effluent. Absorption pits are recommended as an alternative when absorption fields/ trenches are not practicable and where the topsoil is underlaid with porous soil or fine gravel. The capacity of an absorption pit can be computed on the basis of percolation tests to be made at the disposal site.

Soakaways or soakage pits (Figure 9.16) are mostly used in Bangladesh. The septic tank effluent flows through pit walls made of open jointed bricks, into the surrounding soil. Typically, soakaways can be 2 to 3.5 m in diameter, and 3 to 6 m deep depending on the amount of wastewater flow and the infiltration capacity of soil.

Evapotranspiration mounds: A mound system is a soil absorption system that is elevated above the natural soil surface in a suitable fill material. The purpose of the design is to overcome site restrictions that prohibit the use of conventional sub-surface absorption systems. The design of a mound for a particular site involves five steps: (a) sizing of the required base area, (b) sizing of the absorption trenches, (c) design of the distribution system, (d) final dimensioning of the mound, and (e) sizing of the dosing chamber.

Disposal to nearby sewer: When the soil is essentially impermeable and hence the conventional sub-surface absorption system of septic tank effluent disposal is not possible, then the tank should be connected to a small-bore sewerage system for off-site disposal. However this is possible only when a newly laid sewer line passes nearby an existing septic tank.

Treatment and disposal of sludge

Sludge and scum must be removed from the tank when they occupy 2/3 of tank capacity. This operation is usually carried out every 2 to 5 years. Sludge accumulates at a rate of 0.04 to 0.06 m^3/person/year. Sludge disposal should be done with caution because of survival of pathogens. The most satisfactory method of sludge removal is to use a tanker lorry equipped with a pump and suction hose. When a tanker is unavailable, it can be removed manually. In some tropical areas, anaerobically digested septic tank sludge is used as a soil-conditioner or fertilizer for fish ponds.

Operation and maintenance

Annual inspections are required to determine the depth of scum mat and sludge accumulation. Failure to desludge when required may cause carry-over of solids and consequent clogging of the disposal system. In such a case, not only will the tank need to be cleaned, but the disposal system need to be reconstructed.

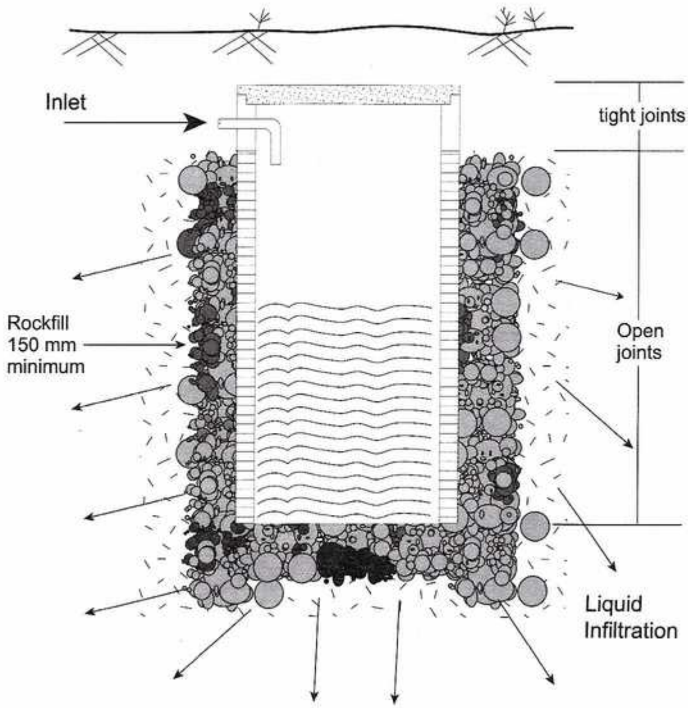

Figure 9.16 Typical soakage pit

The frequency of desludging cannot be predicted with any degree of certainty, but an estimate may be made assuming a sludge accumulation rate of 0.04 m^3/person/year and a liquid retention rate which does not fall below 24 hours. Typical desludging periods vary between 2 and 5 years. For most satisfactory operation the municipal authority should undertake desludging.

9.9 COMMUNAL SANITATION SYSTEM

A communal sanitation system consists of a number of squatting facilities with a common disposal system. Communal sanitation facilities are provided where sewerage systems are not feasible both technically and economically, and where on-site individual sanitation systems are not possible due to housing density and ground conditions. These communal sanitation systems may either consist of toilet facilities only or a combination of toilet, shower and laundry facilities. Figure 9.17 illustrates a typical communal sanitation facility.

It is to be noted that there is a clear distinction between communal sanitation facilities and public toilet facilities. Communal facilities are built outside household plots in communities and used by people for their daily needs when at home. Public toilet facilities are built in or near market places, commercial areas, city centres and other public places and are intended for people who are away from their homes. However, in view of similarities in design, construction and maintenance of both communal sanitation and public toilet facilities, communal sanitation is used here to represent both types. Sanitation for schools and other institutions are in some ways similar to communal sanitation facilities.

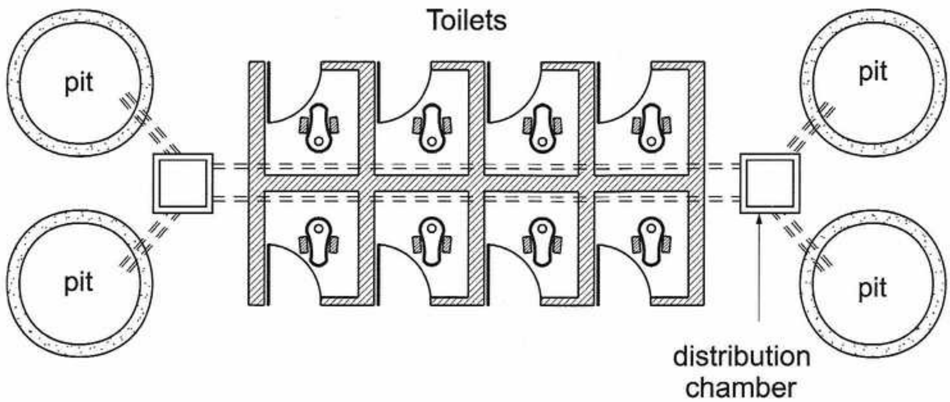

Figure 9.17 Typical communal sanitation facility

Generally it is recommended that one toilet compartment be used by at least 25 or more people. This is according to an Indian rule for communal latrines based on an average of seven and a half minutes for defecation over three hours when the latrines are used in the mornings (Pickford, 1995). For intermediate solutions and in emergency areas a higher number of people per toilet may be accepted. However, a long queue may discourage people to use a communal sanitation facility and uncontrolled open defecation may take place.

Communal sanitation facilities should be provided with a piped or tubewell water supply sufficient for flushing, anal cleansing, hand washing and if available, for shower and laundry facilities. The communal toilets can be of a manually flushed type (e.g., pour-flush toilets) or low volume cistern flushed type toilets. Ten to twenty litres of water per capita daily may be required for toilet use only and an additional 20 to 40 litres per capita per day for shower and laundry facilities.

Communal latrines can be connected with leach pits, conventional sewerage systems or small bore sewer systems depending upon availability of funds and existing sanitation systems in the adjacent area.

Advantages and disadvantages of communal sanitation

The important advantages of a communal sanitation system are as follows:

- The option is suitable for densely populated slum areas where individual on site system is technically and economically unfeasible.
- The users can share total costs of communal sanitation facilities, leading to low per capita cost compared to the high technical standard of the facility.
- Communal sanitation facilities, if connected to a biogas plant, may provide significant amount of energy required for cooking and lighting.

The disadvantages are as follows:

- There is a lack of commitment by individual users to keep the communal facilities clean and operating properly.
- There is a lack of privacy particularly for women.
- They are difficult to use at night and in bad weather, especially for children, the sick and the elderly.
- They require for scarce public land, which in a crowded shanty town may be up to 10% of the total land area available.
- Communal sanitation facilities cannot be upgraded to individual household sanitation facilities.

Operation and maintenance of communal sanitation

Communal sanitation facilities have been used in different parts of the world in many different forms for a long time. Yet in most instances these facilities, irrespective of the type of design, have proved to be failures. The primary reason is their operation and maintenance. All over the world the main problem is keeping these facilities clean, as the users are not motivated to do this when this is not part of their housing. Fouling of latrines and urinals is common and once a latrine is fouled, subsequent users find no other alternative but to foul it more. The major problem is who is to keep the facility clean.

Apparently, the way to avoid the unhygienic conditions in communal sanitation facilities is to employ a full-time attendant for operation and maintenance. Appropriate fees may be charged for use of the sanitation facilities and the money thus collected may be used to pay for the salary of the attendant and the rest spent for maintenance. It is to be stressed, however, that the problem of cleaning can be effectively overcome if the community genuinely wants a community latrine, contributes to its construction and plans a cleaning programme before construction starts. Attendants should be employed and paid by the community rather than by the government because government employees may not do the job properly, as they are paid the same fixed amount irrespective of whether the latrines are clean or filthy.

Operation and maintenance of communal sanitation facilities by contractors or through private leasing are reported (Pickford, 1995) to be successful. By 1993 Sulavh International, a large NGO, had built and was maintaining more than 2,500 sanitation complexes in India. They operate on the 'pay and use' principle and most of them include showers and washing facilities as well as latrines.

The appearance of some complexes was made attractive, with greenery planted around the buildings. Sulavh also constructed a 54-seat communal facility at Patna in 1982, which fed an underground digester that produced about 55 m^3 of biogas a day. This gas was used to power a 10 kVA generator which produced electricity to light the complex itself, an adjoining park and street lights along four kilometres of busy city road.

9.10 WORKED EXAMPLES

Example 1

Design a low-cost simple pit latrine for a family of six persons. The soil in the area is fairly permeable and stable. The groundwater table is 5 m below ground level. Determine the size of the pit required for a period of five years. The family uses water for anal cleansing.

Solution: Assume that the pit would be above the groundwater table and therefore can be considered as a dry pit. Hence the value of *C*, with water being used for anal cleansing, can be taken as 0.06 m^3/person/year. As the soil is very permeable, the liquid part will percolate into the soil fairly quickly.

From the relation, $V = 1.33 \times C \times P \times N$,

The required volume of the pit $= 1.33 \times 0.06 \times 6 \times 5$
$= 2.4\ m^3$

To limit the size of the squatting plate for practical reasons, the size of a circular pit should be in the range of 1.0-1.5m in diameter. For the present case, a 1.25m diameter circular pit is considered.

Cross-sectional area of the pit $= \pi D^2 / 4$
$= \pi \times (1.25)^2 / 4$
$= 1.23\ m^2$

Depth of the pit $= \dfrac{\text{volume of the pit}}{\text{cross-sectional area of the pit}}$

$= 2.4 / 1.23 = 1.95$ m

Excavate a pit of depth = 2.0 m

A rectangular pit can also be considered.

Assume a section of 1.25 m x 1.25 m for the present case.

Area of the cross-section $= 1.25 \times 1.25$
$= 1.56\ m^2$

$$\text{Therefore, the required depth} = \frac{\text{volume required}}{\text{cross-sectional area}}$$

$$= 2.4 / 1.56$$
$$= 1.54 \text{ m}$$

Choose a depth of 1.7 m.

Example 2

Design a VIP latrine for a family of eight. The family uses water for anal cleansing. The groundwater table is only 2.0 m below the ground surface.

Solution:

(a) Single pit option

Assume that the latrine pit will be above the groundwater table and hence dry.

$\therefore$ the solids accumulation rate, $C = 0.05$ m^3 per person per year

Using equation 9.1 and assuming that the pit will be emptied every three years,

$$V = C \times P \times N$$
$$= 0.05 \times 8 \times 3 = 1.2 \text{ m}^3$$

Suitable pit dimension would be 1.0 m x 1.2 m, with a depth of 1.5 m including 0.5 m free space. Thus the pit base is still above the groundwater table, so the pit will remain dry.

(b) Alternating twin-pit option

If the emptying cycle is three years as for the single pit system, then the dimension of each pit would remain the same, i.e., 1.0 m x 1.2 m x 1.5 m.

A two year cycle would result in smaller pits.

$$V = C \times P \times N$$
$$= 0.05 \times 8 \times 2$$
$$= 0.8 \text{ m}^3$$

The dimension of each pit would be 0.8 m x 1.0 m, with a depth of 1.5 m including 0.5 m free space.

Note:

Since the pit bottom is a very close to the groundwater table, it is suggested that the pit bottom be sealed with a clay lining or lean concrete and that 0.5 m annulus sand be placed between the pit lining and the soil in order to reduce the risk of groundwater contamination.

Example 3

A farmer excavated a pit measuring 1.5 m x 2.0 m x 2.5 m (depth) to use the excavated soil in the construction of an extra room for his son who is coming home after graduation from a college in town. Now he wants to convert this pit into a latrine to serve his family of six members for a long period. His son does not like to see excreta below while defecating. The water supply in the village is through handpump tubewells which means that the quantity of water available for latrine use is limited. Furthermore the groundwater table is very low. Anal cleansing practice in the village is by using water. Design a suitable sanitary latrine to be built over the excavated pit.

Solution: Four necessary conditions for this problem are:

- the excavated pit is to be used;
- the system should be a low-cost one;
- water available for use in the latrine is limited;
- the excreta must not be seen during defecation.

The possible solutions satisfying the above conditions could be to install aqua-privy, off-set pit pour-flush or the ROEC latrine. The aqua-privy and the pour-flush latrines require relatively more water than the ROEC latrine. Therefore, the ROEC type latrine is recommended.

Since not much water is added and the groundwater table is very low, the pit can be considered as a dry pit. Since anal cleansing is done using water, the solids accumulation rate, C is taken as

$$C = 0.06 \text{ m}^3 \text{ /person /year}$$

The lining of the pit will decrease the volume of the excavated pit to some extent. Keeping a provision of 0.5 m for the pit lining, the effective volume of the pit is given by:

$$\begin{aligned} V &= \text{width x length x depth} \\ &= (1.5 - 0.5) \times (2.0 - 0.5) \times 2.5 \\ &= 1.0 \times 1.5 \times 2.5 \\ &= 3.75 \text{ m}^3 \end{aligned}$$

The pit volume is also given by:

$$\begin{aligned} V &= 1.33 \times C \times P \times N \\ \text{or} \quad 3.75 &= 1.33 \times C \times P \times N \\ \text{or} \quad 3.75 &= 1.33 \times 0.06 \times 6 \times N \\ \text{or} \quad N &= 3.75 / (1.33 \times 0.06 \times 6) \\ &= 7.83 \text{ years} \end{aligned}$$

Hence, the excavated pit can be turned into a ROEC latrine, which is expected to serve the family satisfactorily for about eight years, provided the chute is regularly cleaned to avoid odour and fly nuisance.

Example 4

Design a leach pit for both single and alternating twin off-set pit pour-flush latrines serving a family of eight members living in a peri-urban area. Wastewater flow is 12 lcd and the soil is a porous silty loam.

Solution: Pit volume with respect to infiltration

Infiltration rate for porous silty loam (from Table 9.2) is,

$$I = 20 \text{ l/m}^2 \text{ day}$$

Total wastewater flow is,

$$Q = 8 \times 12 = 96 \text{ litres per day}$$

Area required for infiltration is,

$$A_i = Q/I = 96/20 = 4.8 \text{ m}^2$$

Assuming a circular pit of diameter 1.2 m,

we have volume,

$$V_i = A_i D / 4$$
$$= 4.8 \times 1.2 / 4 = 1.44 \text{ m}^3$$

Pit volume with respect to solids storage

Considering solids accumulation rate, $C = 0.04$ m^3 per person per year and emptying interval, $N = 2$ years, the pit volume can be determined by using equation (9.1),

i.e.,

$$Vs = C \times P \times N$$
$$= 0.04 \times 8 \times 2$$
$$= 0.64 \text{ m}^3$$

Case 1: Single pit pour-flush system

The effective volume, V = Vi + Vs = 1.44 + 0.64 = 2.08 m^3, say 2.25 m^3

Considering pit diameter of 1.2 m, effective depth, $h = V / (\pi D^2 / 4)$

$$= 2.25 / (\pi \times 1.2^2 / 4)$$
$$= 2.0 \text{ m}$$

Assuming 0.5 m clear space, total depth = 2.0 + 0.5 = 2.5 m

The depth can, however, be varied by changing the diameter of the pit, e.g., 1.8 m deep for a 1.5 m diameter pit.

Case 2: Alternating twin-pit pour-flush system

Here the volume with respect to infiltration governs, and therefore the effective volume of each pit will be equal to $V_i = 1.44\ m^3$.

Assuming the diameter of each pit as 1.2 m, the depth of each pit would be = 1.8 m (considering 0.5 m clear space).

The suitable dimensions of each pit would then be: 1.2 m dia, 1.8 m deep.

Example 5

Design a septic tank to serve a household of ten persons who produce 90 lpcd of wastewater. The tank is to be desludged every three years.

Solution:

Sedimentation

Minimum mean hydraulic retention time,

$$t_h = 1.5 - 0.3 \log (Pq)$$
$$= 1.5 - 0.3 \log (10 \times 90) = 0.61 \text{ days.}$$

The volume required for sedimentation is given by:

$$V_h = 10^{-3} (Pq)t_h$$
$$= 10^{-3} (10 \times 90)\ 0.61 = 0.55\ m^3$$

Sludge digestion

Assuming a design temperature of 25° C

$$t_d = 30 (1.035)^{35-T}$$
$$= 30 (1.035)^{35-25}$$
$$= 42.3 \text{ days}$$

Volume required for sludge digestion

$$V_d = 0.5 \times 10^{-3} \times Pt_d$$
$$= 0.5 \times 10^{-3} \times 10 \times 42.3 = 0.21\ m^3$$

Sludge storage

Assuming sludge accumulation rate, $C = 0.06\ m^3$ per person year

$$V_{sl} = CPN$$
$$= 0.06 \times 10 \times 3$$
$$= 1.8\ m^3$$

Overall effective tank volume

$$\begin{aligned} V &= V_h + V_d + 1.4V_{sl} \\ &= 0.55 + 0.21 + (1.4 \times 1.8) \\ &= 3.28\ \text{m}^3 \end{aligned}$$

Tank effective depth

Assume a cross-sectional area, $A = 3.0\ \text{m}^2$

the maximum depth of sludge, $d_{sl} = V_{sl}/A = 1.8 / 3.0 = 0.60$ m.

the maximum submerged scum depth, $d_{ss} = 0.4\ V_{sl}/A = 0.4 \times 1.8 / 3.0 = 0.24$ m

Scum clear depth = 0.075 m (minimum)

Sludge clear depth = (0.82 – 0.26 x 3.0)

= 0.04 m < 0.3 m \ 0.3 m is adopted.

The total clear space depth

= (0.075 + 0.3) = 0.375 m.

Depth required for sedimentation

= $V_h/A = 0.55 / 3.0 = 0.183\ \text{m} < 0.375\ \text{m}$

∴ The total clear space depth is the controlling factor in the design.
The total effective depth is therefore, the sum of the sludge depth (0.60 m), the clear space depth (0.375 m), and the maximum submerged scum depth (0.24 m).

i.e., the total effective depth

= 0.60 + 0.375 + 0.24 = 1.215 m

The suitable overall internal dimensions of the septic tank can be chosen as follows:

1.0 m x 3.0 m x 1.5 m

Use a two-compartment septic tank with the first compartment volume of 3.0 m^3 and the second compartment volume of 1.5 m^3.

Example 6

If the soil is sandy loam with a long-term infiltration rate of about 30 l/m^2 day, design a soakage pit for the disposal of effluent from the septic tank of the previous example.

Solution: Effluent flow from septic tank = 90 x 10 = 900 litres/day
Long-term infiltration rate = 30 litres / m^2 day
The infiltration area required = Q / I
= 900/30 = 30 m^2

Assuming a 1.25 m diameter, the effective depth of the soak pit will be
= 30 / π x 1.25
= 7.6 m

However, if the groundwater table is high, two soak pits each of 1.25 m diameter and 4.0 m deep may be provided. Alternatively, if sufficient land area is available, drain-field trenches can also be designed for the disposal of septic tank effluent.

Questions

1. Briefly discuss the suitability of a conventional simple pit latrine. What is the main disadvantageof this system?

2. What are the basic elements of a VIP latrine technology? How can the main disadvantage of a simple pit latrine be improved in a VIP latrine system?

3. What variation does the ROEC have from the VIP technology? Briefly discuss the merits and demerits of ROEC and also its applicability.

4. Briefly discuss the technical aspects of compost latrines. What factors may restrict its its succesful application in Bangladesh.

5. What is the basic improvement made in the pour-flush sanitation technology compared to simple pit and VIP technologies? What are the major components of a pour-flush sanitation system?

6. Classify the various types of pour-flush sanitation systems and discuss their relative advantages and disadvantages and their applicability. How can operation and maintenance of each type influence their applications?

7. Briefly describe the design principles of pour-flush leach pits. Discuss the groundwater pollution potential from the contents of these leach pits. How this can be minimized?

8. Discuss the various important processes that take place in a septic tank. Briefly describe the design procedure of a septic tank.

9. Prepare a schematic diagram showing various components of a septic tank. Position the inlet and outlet devices carefully and explain how these can influence the septic tank operation.

10. Distinguish between communal sanitation and public toilet facilities. What is the primary reason for failures of such communal and public sanitation facilities? How can these services be made sustainable?

11. In an effort to discourage people from open defecation the local authority in a village offers pre-cast concrete rings of 1.0 m diameter and concrete slabs to cover the pits at a very subsidized rate. Design a simple pit latrine for an average family of 7 persons who uses water for cleansing. The groundwater table is below 5.0 m and the latrine is to serve the family for at least 4 years.

12. A simple pit latrine designed, as in the previous example, for 4 years for 7 persons has already been used for 2 years, and it has a circular pit of 1.0 m diameter. The local authority now offers an improvement opportunity by offering pre-cast slabs with an in-built waterseal pan. The water supply situation of the village has also been improved by providing hand tubewells within 60 metres of each house. The users of the simple pit latrine now want to upgrade the latrine into a pour-flush latrine. Determine the total life period of the existing pit as a pour-flush unit before emptying for the first cycle and subsequent cycles.

13. Design leach pits for a twin off-set pit pour-flush sanitation unit for a family of 8 members having a life period of 2 years. The average wastewater flow rate is about 10 litres per person per day. The soil is porous silty loam with a long-term infiltration rate of 20 l/m^2 day.

14. Design a septic tank for a family of 10 persons with a desludging interval of 5 years. The average wastewater flow is 15 litres per capita per day. Also design the soak pit for the disposal of the septic tank effluent. The soil is silty loam with a long term infiltration rate of 20 l/m^2- day

15. A common septic tank is to be designed for three adjoining houses with a total of 21 users. The average wastewater flow rate is 180 litres/capita/day. Design a suitable septic tank and show only the dimensions of the septic tank.