

## **5.**

# **2nd Phase Technical Options**

This chapter presents a range of standard technical options for 2nd phase emergency implementation. It should be used to identify possible solutions for a specific situation. Solutions for more difficult environments are presented in Chapter 6. The final choice of option(s) should be decided upon only after in depth CONSULTATION with the intended users.

This chapter considers the following technical options:

- Simple pit latrines
- Ventilated improved pit (VIP) latrines
- Eco-San options
- Borehole latrines
- Pour-flush latrines
- Septic-tanks
- Aqua-privies
- Wastewater treatment systems
- Latrines for institutions (schools, clinics etc.)

The basic characteristics and design parameters for each option are presented below. Supporting technical design information can be found in Chapter 7 and detailed bills of quantities are provided in Appendix 4 where indicated.

## 5.1 Simple pit latrines

Simple pit latrines are by far the most common technology choice adopted in emergency situations. This is because they are simple, quick to construct and generally inexpensive.

The **pit should be as deep as possible** (and at least 2m in depth) and covered by a latrine slab. The rate at which the pit will fill will depend on the sludge accumulation rate and the infiltration rate of the soil and the required size of the pit can be estimated based on these (see Section 7.3). At least the top 1m of the pit should be lined to prevent collapse, and where the soil is suspected to be unstable the entire pit should be lined. There are a number of lining options that can be used (see Section 7.3).

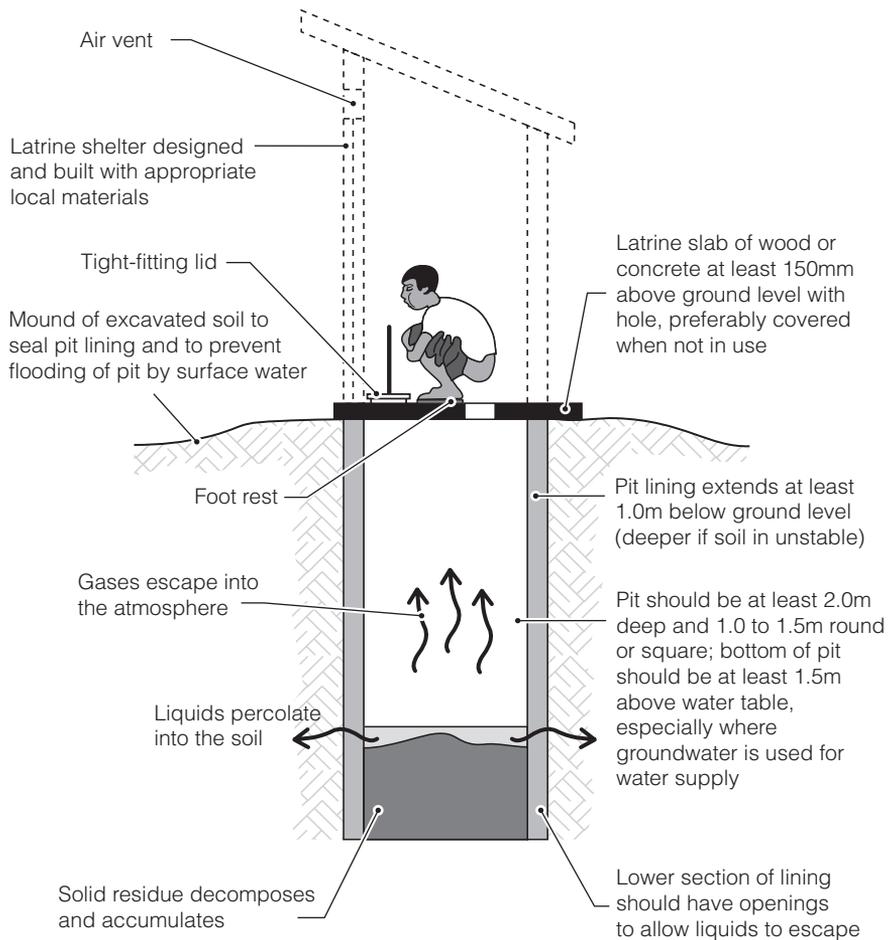
The slab can be made from concrete or wood, or a prefabricated plastic slab can be used (see Section 7.4). This should be firmly supported on all sides and raised above the surrounding ground level to prevent surface water entering the pit. A squat or drop-hole is provided in the slab which allows excreta to fall directly into the pit – this can be covered with a removable lid to minimize flies and odour.

The superstructure can be made from materials available locally, such as wood, mud and grass, or can be a more permanent structure of bricks and mortar.

**Advantages:** Cheap; quick to construct; no water needed for operation; easily understood.

**Constraints:** Unsuitable where water-table is high, soil is too unstable to dig or ground is very rocky; often odour problems.

See **Appendix 4.2** for a bill of quantities for a simple pit latrine.



**Figure 5.1. Simple pit latrines**

## 5.2 Ventilated-improved pit (VIP) latrines

The Ventilated Improved Pit (VIP) latrine is an improved pit latrine designed to minimize odour and flies. This is more expensive than the simple pit latrine and, in emergency situations, is generally **only viable for institutions** such as hospitals or schools.

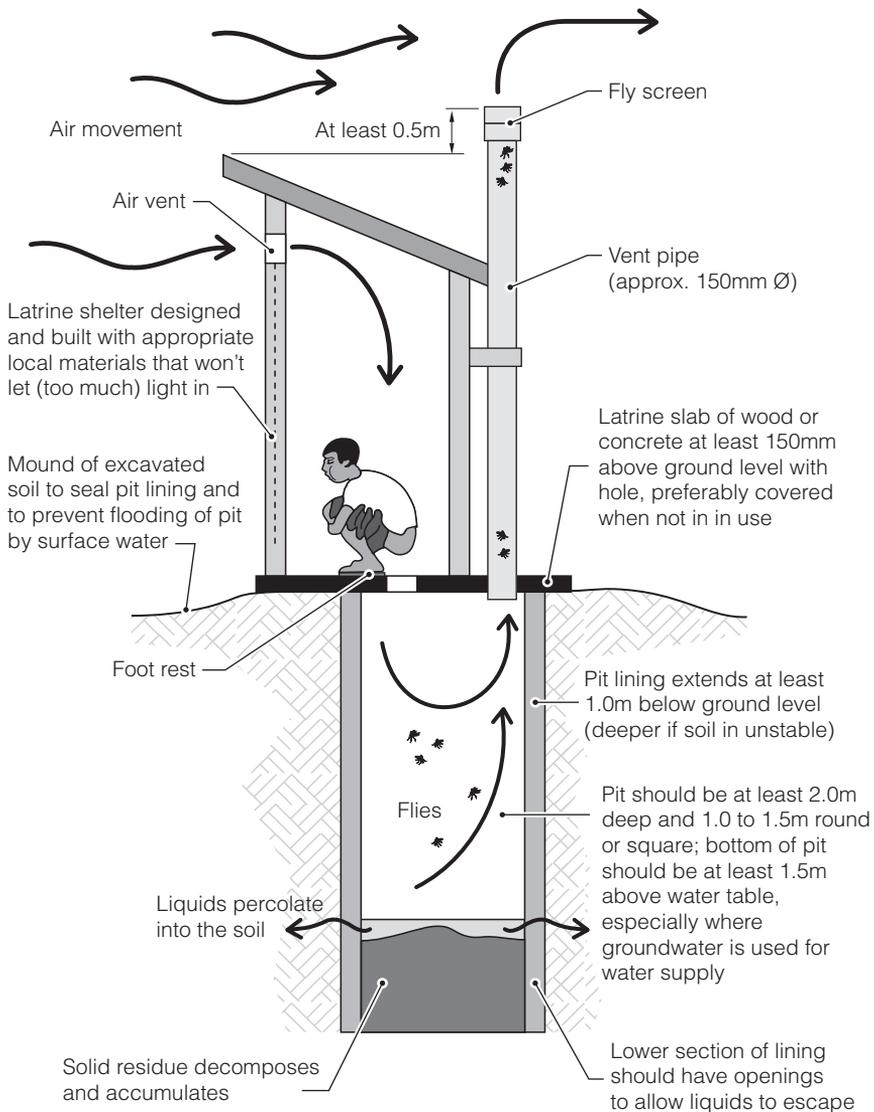
A **vent pipe** covered with a **gauze mesh or fly-proof netting** is incorporated into the design to remove odorous gases from the pit, prevent flies entering the pit and trap any flies trying to leave. The pipe should **extend at least 0.5m above the superstructure roof** to ensure the air flow is unobstructed, and should be at least 30cm from the squat hole. The movement of air across the top of the vent pipe creates low pressure which promotes upward air flow within the pipe and aids ventilation. The vent pipe can be situated inside or outside the latrine interior. Inside has the advantage that the latrine slab is easier to construct since the superstructure can be built around it, and outside has the advantage that the pipe warms quicker which encourages air flow through it. Air should be able to flow freely through the squat hole and vent pipe; therefore **no drop-hole cover** is required.

The superstructure interior should be kept reasonably dark to deter flies, but there should be a gap, usually above the door, to allow air to enter. This gap should be at least three times the cross-sectional area of the vent pipe (Franceys et al., 1992). Air flow can be increased by facing the door of the superstructure towards the prevailing wind. Each drop-hole should have its own compartment and there should always be **one vent pipe per compartment**.

**Advantages:** Reduced odour; reduces flies; good-quality. Long-term solution.

**Constraints:** Difficult and expensive to construct properly; design and operation often not fully understood; construction may take time; dark interior may deter young children from use; does not deter mosquitoes; low replicability as PVC pipes are expensive; increased odour outside.

See **Appendix 4.4** for a bill of quantities for a VIP latrine.



**Figure 5.2. VIP latrines**

### **Vent pipe details**

The vent pipe mesh or netting should have a mesh size of between 1.2 and 1.5mm. The gases given off by the decomposition of excreta are very corrosive. For this reason, fly mesh made from mild steel will rot very quickly and plastic mesh will last about two years. Mosquito netting is often used but aluminium or stainless steel is the best material for this purpose.

A wide variety of materials can be used for the vent pipe, such as uPVC, asbestos cement, fired clay, concrete or even mud-covered bamboo or reed. If the pipe is smooth inside (such as plastic or asbestos cement) then an **internal diameter of 150mm** is recommended. The smallest PVC pipe diameter that can be used is 110mm, but only if larger diameters are not available. Otherwise vent pipes should be at least 200mm in diameter or square. Where large-diameter pipes are not available, or are too expensive, an alternative is to construct the vent pipe from block or brickwork.

A simple test can be used to check that the vent pipe is having the desired effect and that air is flowing from the pit up through the pipe. When a small amount of ignited paper and/or dry grass is dropped into the pit smoke should be seen rising from the top of the vent pipe if the ventilation effect is functioning correctly.

The majority of design and construction information for a VIP latrine, such as pit and slab design, is the same as for a simple pit latrine (see Chapter 7 for more information).

### 5.3 Eco-San

Ecological sanitation (or Eco-San) refers to excreta disposal solutions which recycle nutrients from human excreta for agricultural production. Eco-San options can be defined in several different ways but the most common options are the:

- **Double-vault urine-diverting latrine** which uses a dry disposal system in which urine and faeces are managed separately, and ash, carbon or sawdust is added to the vault contents; and
- **Double-vault non-urine-diverting latrine** in which urine is not separated from faeces but soil, ash and organic waste is added to the vault contents.

Both options are designed so that one vault is used initially, then sealed when full. The second vault is then used until that is full, at which point the first vault can be emptied and the stored waste re-used (for agricultural purposes). In order to make the waste safe for handling and most effective as a fertilizer, sufficient time is required to reduce the pathogen content of the waste. The vault size must be carefully calculated to ensure that the waste is retained for one to two years. Heavy usage, as is likely in many emergency situations, may lead to serious problems because of inadequate time for decomposition.

The following factors have a positive effect on reducing pathogen survival in ecological latrines (Sugden, 2006):

- increasing storage time (by using large pits or vaults);
- reducing the moisture content (ideally below 25%, by separating urine from faeces, heating, or adding wood ash or soil to absorb moisture from faeces);
- increasing the pH (ideally to above 10, by adding ash or lime – though this may have an impact on the effectiveness of the final waste product as a fertilizer);
- increasing the temperature (ideally above 36°C, by adding green organic material or using a solar-drying plate);
- encouraging the presence of other micro-organisms (by adding soil containing fungi and micro-organisms capable of predation).

## **Double-vault urine-diverting latrine**

In the double-vault urine-diverting latrine (sometimes known as a dehydrating latrine) the deposited faecal matter is dried by exposure to heat or the sun and the addition of wood ash, carbon, sawdust or earth, which controls the moisture content. In El Salvador a 3:1 mixture of sawdust and ash or a 5:1 mixture of dry earth and lime is recommended, a handful of which should be added after each use. The latrine contents are then isolated from human contact for a specified period to reduce the presence of pathogens and make the waste safe for handling. This period should be **at least ten months** and some practitioners recommend longer periods of up to two years. The longer the waste is stored the more pathogens will be destroyed. The waste may then be re-used as fertilizer or as fuel.

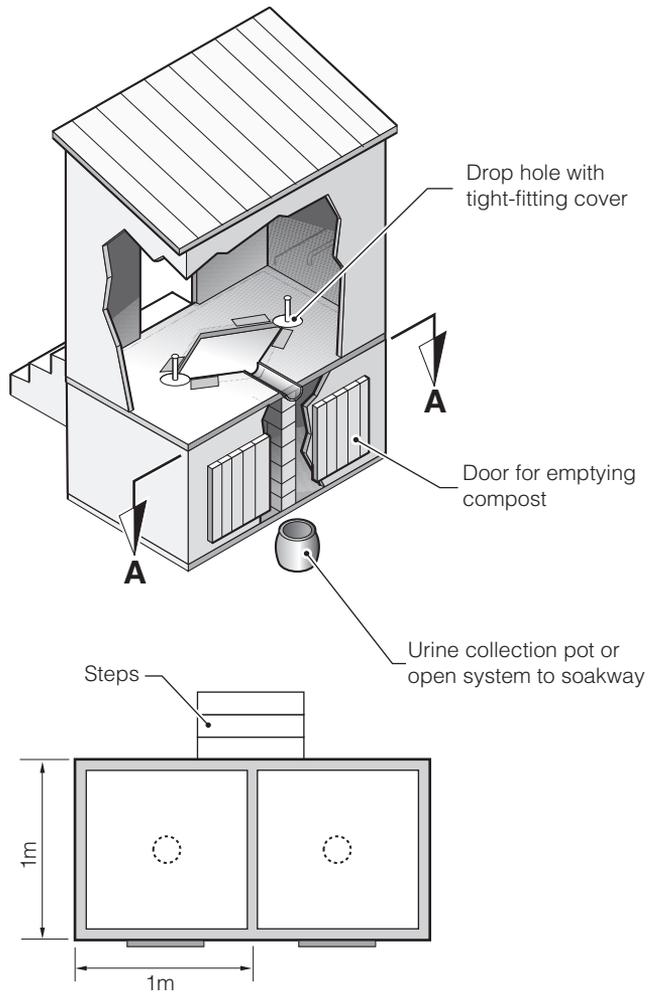
The vaults can be constructed above or below ground, but above ground has the advantage that contents can be emptied more easily and there is less risk of groundwater contamination. An adaptation of the urine-diverting latrine is the solar urine-diverting latrine in which the vaults are extended at the rear of the latrine and covered with a metal plate. This is painted black and oriented to receive maximum solar insolation in order to increase the temperature of the vault contents.

The primary difficulty in using this type of toilet is the separation of urine and faeces. Users have to be made aware of the importance of separation and the addition of ash after defecation. Such a system is unlikely to work where water is used for anal-cleansing since this will increase the moisture content. In general, urine-separation latrines are not appropriate in the initial stages of an emergency, due to the time taken to educate, train and construct. However, they require no water and can be adopted where infiltration techniques are impossible – and may be a viable longer-term option.

**Advantages:** Reduced odour; ideal where the affected population normally uses Eco-San latrines and agricultural activity occurs; raised latrines can be used to prevent groundwater contamination.

**Constraints:** more difficult to construct than simple pit latrines; high level of user awareness and diligence required; complex to operate and maintain.

See **Appendix 4.5** for a bill of quantities for a double-vault urine-diverting latrine.



**Figure 5.3. Double-vault urine-diverting latrine**

### **Double-vault non-urine-diverting latrine**

The double-vault non-urine-diverting composting latrine (also known as the Fossa Alterna) is very similar to the urine-separation latrine. It also has two vaults or pits which are used alternately and can be constructed above or below ground level. The waste must be stored for at least one year (and preferably two years) before re-use.

The principal difference between the two latrine types is that urine is not separated from faeces which makes it easier to construct and use. In order to raise the temperature and increase the effectiveness of the waste as a fertilizer the composting process is encouraged through the addition of earth, wood ash and green organic material. A 3:1 mixture of dry earth and ash can be added after each use to raise the pH and encourage predation. Vegetable or other organic waste such as food residue can also be added to control the chemical balance. A solar heating plate can also be used to help raise the temperature.

Once the pit or vault is two-thirds full it should be topped up with earth to allow anaerobic composting to take place while the second pit is in use.

**Ecological latrines are not appropriate in most emergencies. However, they may be appropriate if the population is already accustomed to using similar systems or if family latrines are to be constructed in an agricultural area. Raised latrines can also be effective in preventing contamination of shallow groundwater.**

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**Photograph 5.1. Solar urine-diverting latrine in El Salvador**

### **Biogas latrines**

Biogas technology, whereby the gas given off by decomposing excreta is captured and used for fuel, has been promoted in some low-income countries such as China, India, Nepal, Thailand, Cambodia and Vietnam. Low-cost, plastic-tubular biodigesters can be used to digest large volumes of human or animal waste to provide gas which is used as cooking fuel. This technology may be appropriate where there is local indigenous experience and expertise in designing and managing such plants. It is not, however, appropriate for the majority of emergency situations where this expertise is not available.

## 5.4 Borehole latrines

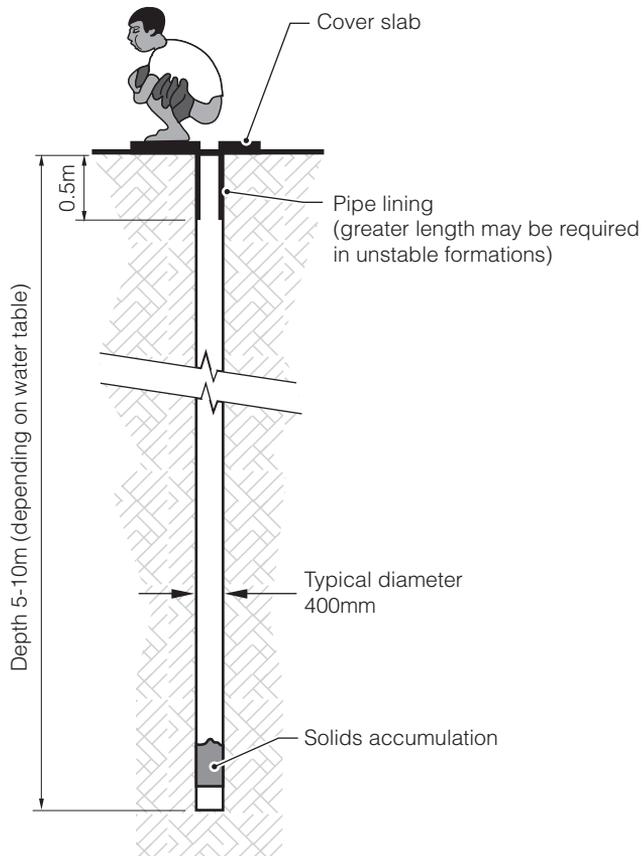
Borehole latrines can be constructed very rapidly if an auger or a drilling rig is available. A deep soil profile (more than 7m) is required which is relatively easy to drill with a hand auger or a mechanical drill. The borehole has a typical diameter of 400mm and a depth of 5-10m. A hole 300mm in diameter and 5 metres deep should last a family of five approximately two years, depending on the material used for anal-cleansing. At least the top 0.5m should be lined although it is rarely necessary or appropriate to line the entire depth.

Borehole latrines are most appropriate in situations where boring/drilling equipment is readily available, where a large number of latrines must be constructed rapidly, and where pits are difficult to excavate, either because of ground conditions or the lack of a suitable labour force.

**Advantages:** The borehole can be excavated quickly if boring equipment is available; suitable in hard ground conditions (where there are no large stones or rocks); and appropriate where only a small workforce is available.

**Constraints:** Drilling equipment is required; there is a greater risk of groundwater pollution due to greater depth than pit latrines; lifespan is short; sides are liable to be fouled, causing odour and attracting flies; and there is a high likelihood of blockages.

**This option should only be considered in extreme conditions when pit excavation is not possible.**



**Figure 5.4. Borehole latrine**

## 5.5 Pour-flush latrines

Pour-flush latrines rely on water to act as a hygienic seal and to help remove excreta to a wet or dry disposal system. The most simple pour-flush latrines use a latrine pan incorporating a shallow U-bend which retains the water. After defecation, a few litres of water must be poured, or thrown, into the bowl in order to flush the excreta into the pit or sewerage system below. Ideally, adequate water must be made available near to latrines. If this is not possible, people may take their own containers when using toilets.

Pour-flush latrines may be constructed directly above a pit or may be offset whereby the waste travels through a discharge pipe to a pit or septic-tank.

Even where there is limited water available, wherever possible pour-flush latrines should be implemented if the population is already accustomed to using them. This is because often such people will not be prepared to use dry systems. Consultation with the community is essential in order to determine the best option.

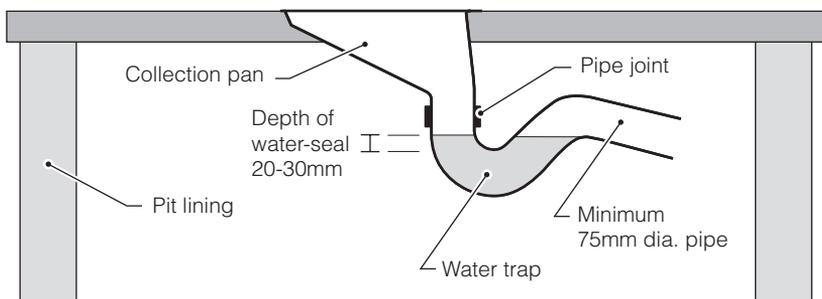
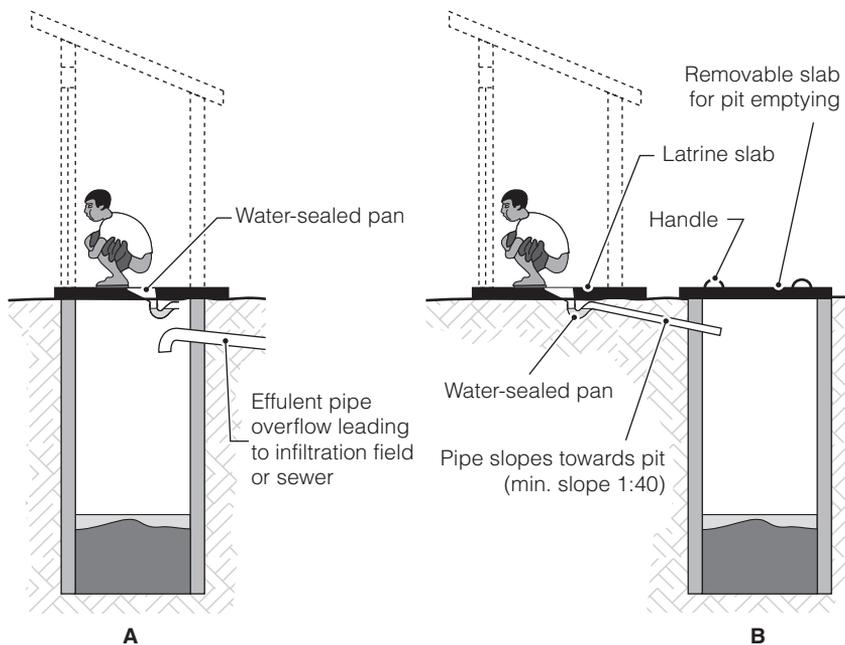
The amount of water required to flush the system will depend on the type and size of the water-seal construction. A 90mm (3") U-bend normally requires 2-3 litres to flush effectively, while a 120mm (4") U-bend generally requires 4-5 litres to flush. These quantities are significantly less than the amount required to flush most water-closet toilets which may use as much as 15 litres per flush.

Where the waste pipe between the U-bend and the pit or tank is more than 2m in length an inspection chamber or **roding point** is needed along its length to allow roding upwards and downwards to prevent blockage (see page 92).

**Advantages:** Lack of odour; ideal where water is used for anal-cleansing; easy to clean; off-set design does not require a self-supporting latrine slab.

**Constraints:** Increased quantity of water required; solid anal-cleansing materials may cause blockages; more expensive than simple pit latrines.

See **Appendix 4.6** for a bill of quantities for a pour-flush latrine.



**Dimensions of sealed pan**

**Figure 5.5. Pour-flush latrines**

## 5.6 Septic-tanks

Where several pour-flush latrines are required these may be used in conjunction with a septic-tank. A septic-tank is designed to collect and treat toilet wastewater and other grey water. Its use is likely to be appropriate where the volume of wastewater produced is too large for disposal in pit latrines, and water-borne sewerage is uneconomic or unaffordable. Septic-tanks are, therefore, particularly suited to systems involving high water use, especially where water is used for flushing and anal-cleansing. However, they are difficult to manage for large populations and are best suited to single households or institutions such as hospitals or schools.

Wastes from toilets, and sometimes kitchens and bathrooms, pass through pipes to a watertight tank where they are partially treated. After one to three days the liquid wastes leave the tank and are carried to a secondary treatment system. This is usually some form of underground disposal system (such as an infiltration field), sewer or secondary-treatment facility.

The treatment process in a septic-tank occurs in four stages:

**Settlement:** Heavy solids settle to the base of the tank to form a sludge which must occasionally be removed; about 80 per cent of the suspended solids can be separated from the liquid in a well-designed tank.

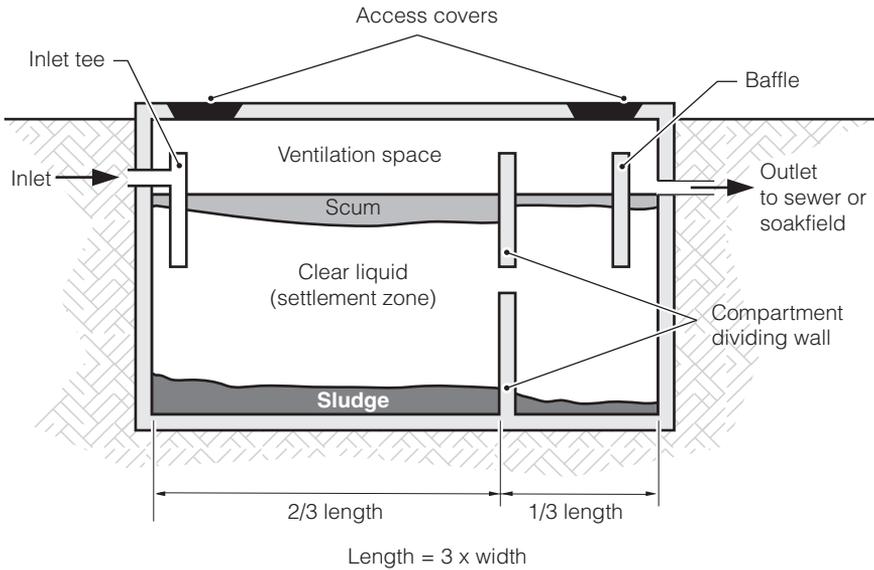
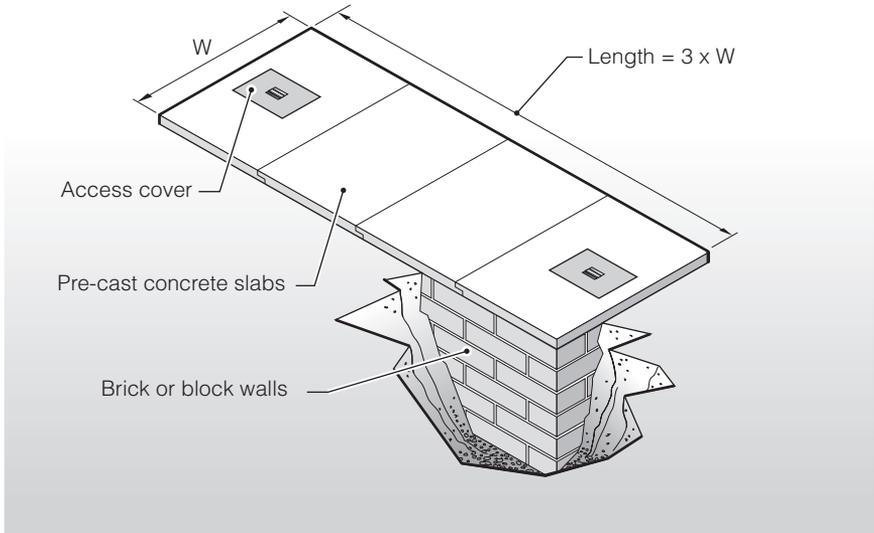
**Flotation:** Grease and oil float to the surface to form a layer of scum; over time this scum layer becomes thick and the surface may be hard.

**Sludge digestion and consolidation:** The sludge at the bottom of the tank is compressed by the weight of new material settling on top, increasing its density; and organic matter in the sludge and scum layers is broken down by bacteria which convert it to liquid and gas.

**Stabilization:** The liquid in the tank undergoes some natural purification but the process is not complete; the final effluent is anaerobic and will contain pathogenic organisms such as roundworm and hookworm eggs.

The final effluent leaving the septic-tank will still be full of pathogens and must be disposed of in an appropriate location such as a soakaway pit, infiltration field or sewerage system. All septic-tanks require a system for removing the sludge and disposing of it hygienically (see Section 8.7).

Detailed design details for septic-tanks can be found in Section 7.7.



**Figure 5.6. Septic-tank**

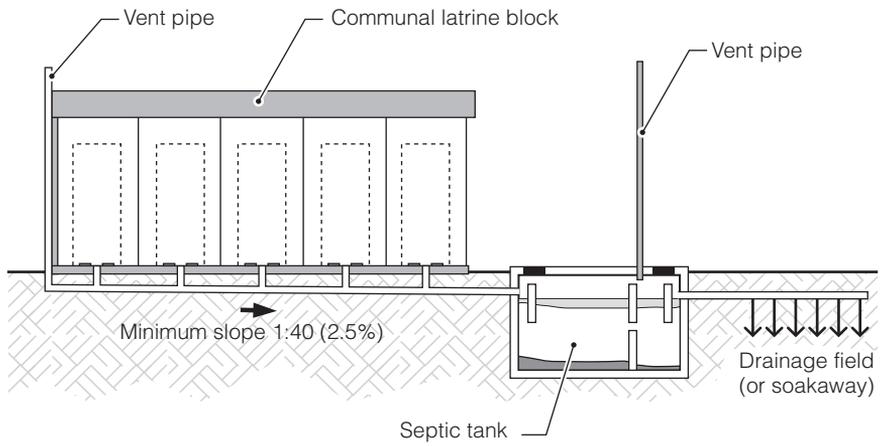
## 5.7 Communal aqua-privies

An aqua-privy is simply a latrine constructed directly above a septic-tank. Aqua-privies are appropriate where pit latrines are socially or technically unacceptable but the volume of sullage is small. The amount of water required for flushing is much smaller than for a septic-tank due to the location of the tank. The water-seal pan and extension of the drop pipe 75mm below the water surface helps to exclude odours from the super-structure. The tank of the aqua privy must be watertight to maintain a constant liquid level in the tank. The outlet pipe should extend at least 50mm below the water surface to provide an odour seal.

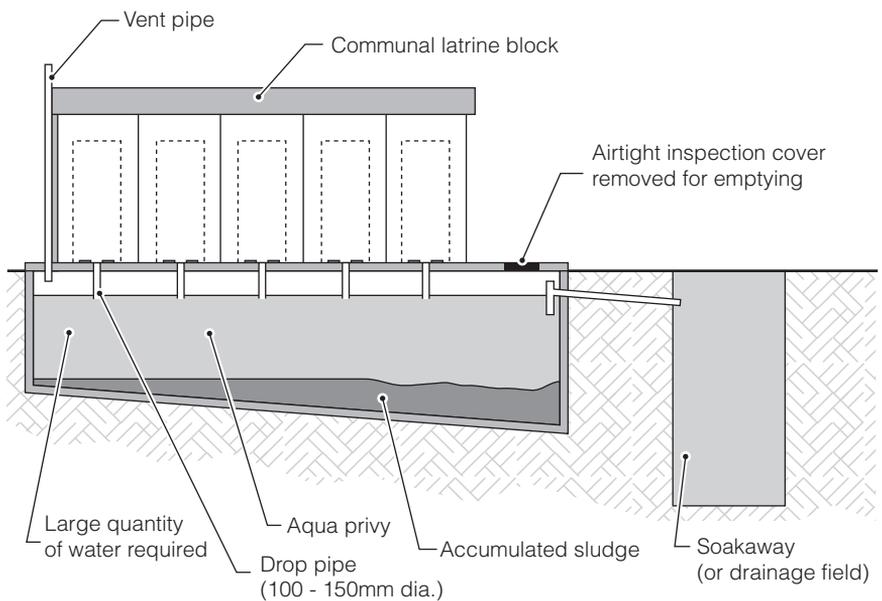
**Advantages:** Reduced odour; ideal where water is used for anal-cleansing; easy to clean; more efficient to empty tank than for individual pour-flush latrines.

**Constraints:** Increased quantity of water required; solid anal-cleansing materials may cause blockages; more expensive and more difficult to construct than simple pit latrines.

An alternative to the communal aqua-privy is the open drain communal latrine (pictured) whereby pour-flush pans discharge directly into a sewage pipe which feeds a septic-tank.



**Open drain communal latrine**



**Figure 5.7. Communal aqua-privy**

## **5.8 Wastewater treatment systems**

In most emergency situations it is possible to use on-site excreta disposal systems whereby human wastes are disposed of without treatment. In some cases, however, it is necessary to treat wastewater prior to disposal. This occurs most often in densely populated areas where traditional on-site solutions cannot be implemented. These include urban environments, rocky terrains that do not allow pits to be dug, where prevention of groundwater contamination is crucial, or where there is simply a cultural resistance to low-technology solutions.

The most simple wastewater treatment system is the septic-tank (as described in Section 5.6) but there are also more advanced treatment technologies that can be used to treat larger volumes of sewage.

### **Collection and transport**

Wastewater treatment systems achieve safe excreta disposal by first collecting and transporting the waste from the toilets. This requires a much smaller area than that required for in-situ solutions providing on-site disposal of excreta such as pit latrines. Collection and transport can be done essentially in one of three ways:

- by temporarily storing the excreta in appropriate tanks and frequently emptying these by vacuum trucks (logistics and operating costs may be a problem with this as is the case with chemical toilets);
- by settling part of the waste in an arrangement similar to a septic-tank and transporting the liquid portion of the waste to the treatment or disposal site by means of a small bore sewerage system by gravity or pumping (this considerably reduces the emptying frequency required but requires water for operation); or
- by transporting the whole waste directly to the treatment or disposal site by means of a larger bore system and more water (these have some of the highest installation costs and require large amounts of water).

## **Treatment and disposal**

The waste, once collected and transported to a more suitable site, may be either disposed of as it is, or treated before disposal into a watercourse or pit. Simple disposal is not recommended due to the high pathogen content of the waste and some form of wastewater treatment is usually required with emphasis on pathogen reduction. Having said this, direct disposal may be the only option in the initial stages of an emergency, and the risk may be mitigated by the addition of lime to pits.

All wastewater treatment systems produce sludge as part of the treatment process either continuously or intermittently. This sludge requires careful handling and can be disposed of in a pit, an incinerator or on agricultural land. See Section 8.7 for more details on sludge disposal.

## **Commercial systems**

There are several package wastewater treatment units available on the market. The main types are:

**Rotating Biological Contactors (RBCs)** which treat the waste by having many disks mounted on a shaft which rotates slowly to alternatively submerge and aerate the biomass on these disks.

**Biological Aerated Filters or Submerged Aerated Filters (BAF/SAFs)** which rely on mobile or fixed submerged media in a tank where the biomass is attached and is continuously aerated from diffusers underneath it.

**Membrane Bioreactors (MBRs)** which rely on submerged membranes within an aerated tank that essentially filter the incoming wastewater.

**Activated Sludge** processes which again rely on continuous aeration followed by a settling stage to recover the biomass. All-in-one tank batch versions of this process exist and are called Sequencing Batch Reactors (SBRs).

### **Advantages:**

- highly automated units which require little maintenance and attention;
- quick to install as they usually come in containerized or trailer-mounted units;
- generally, good performance with built-in disinfection; and
- membranes provide a physical barrier against pathogens.

**Constraints:**

- very expensive for the population served, typically over \$85 per person served;
- generally only suitable for small populations;
- high energy requirements as most are based on aerated processes for compactness;
- require experienced personnel for installation and skilled workers to deal with the electronic controls;
- not designed to treat the highly concentrated waste arising from emergency settlements as this may inhibit their performance; and
- SAFs, BAFs and, to a certain extent, RBCs are not suitable for operation with intermittent power supplies.

## **5.9 Excreta disposal for institutions**

In many emergency situations there is a need to provide excreta disposal facilities for institutions such as hospitals, feeding centres and schools. These will be communal facilities but are normally constructed to a higher standard than domestic communal facilities. In determining the design and layout of institutional facilities, the following factors should be considered:

**Segregation:** Toilet facilities for males and females must be segregated and situated in different parts of the institution's grounds to ensure privacy for women and girls. The number of cubicles required for males can be reduced by building urinals. A ratio of 3 to 1 for female to male cubicles is a useful guideline.

**Convenience:** Facilities should be near enough to the buildings of the institution to ensure that they are used. A **maximum distance of 50m** is recommended.

**Accessibility:** Toilets must be easily accessible to the very young, very old, the weak and infirm, and disabled people. This is especially important for hospitals and schools.

**Handwashing facilities:** Handwashing facilities should be provided alongside latrines. Ideally, there should be **1 tap for every 4 cubicles**.

## 5. 2ND PHASE TECHNICAL OPTIONS

**Privacy:** Handwashing facilities for women and girls should be surrounded by a privacy wall or situated inside to enable them to wash sanitary cloths.

**Security:** Where possible, facilities should not be right next to a fence or institutional boundary where the user may be afraid of intimidation or abuse.

**Operation and maintenance:** Staff should be employed by the institution to ensure that facilities are used and maintained in an appropriate fashion.

**Design:** When sizing pits, sludge accumulation rates should be adjusted based on the number of days and hours spent at the institution. The following equation can be used:

Where: **d** = number of days per week at institution

**w** = number of weeks per year at institution

$$\text{Adjusted sludge accumulation rate (AS)} = \frac{(d \times w \times h) \times S}{24 \times 365}$$

**h** = number of hours per day at institution

**S** = standard sludge accumulation rate (l/person/year)

This can have a big impact on the design of facilities. For example, where a school is attended for 6 hours a day and 5 days a week for 42 weeks of the year, a 'standard' sludge rate of 40 litres/person/day may be reduced 6 litres/person/day by applying this equation.

See Section 7.3 for more details of sludge accumulation rates and pit-sizing details.

There is a range of latrine types that can be used for institutions, including trench latrines, VIP latrines, communal pour-flush latrines (discharging to

a septic-tank as in Figure 5.8) and aqua-prives. In general, toilet blocks consisting of four to six cubicles are easiest to construct and maintain.

### School latrines

School latrines can be made 'child-friendly' by incorporating certain design features, including:

- squat toilets with smaller, 'child-size' holes;
- for younger children, toilets can be open (i.e. with no walls separating them), meaning friends can talk while using the toilet instead of being in a small, dark enclosure;
- providing for child-friendly colourful artwork on the sides of the superstructures; and
- ensuring cubicle interiors are well-lit.

Table 5.1 summarizes the recommended **minimum** number of users per toilet for schools (in all cases numbers should be rounded up).

Schools can also be used to impart hygiene promotion messages to pupils and determine baseline behaviours. Children can be effective facilitators for hygiene promotion – passing on messages to other children and family members.

Intervention agencies can work with schools and local communities to instigate sustainable school sanitation programmes (see Box 5.2).

**Table 5.1. Minimum toilet provision for schools**

Group	Females	Males
Nursery-school children Age: 3 - 5 yrs	1 cubicle per 20 users + 1	1 cubicle per 20 users + 1
Primary-school children Age: 5 - 12 yrs	1 cubicle per 30 users + 1	1 cubicle per 40 users 1 urinal space per 40 users
High-school children Age: 12 - 18 yrs	1 cubicle per 30 users + 1	1 cubicle per 50 users 1 urinal space per 40 users
Teaching staff	1 cubicle per 10 users (with a minimum of 2)	1 cubicle per 10 users

Source: Deverill and Still, 1998

### **Box 5.2.**

#### **Providing school latrines in East Timor**

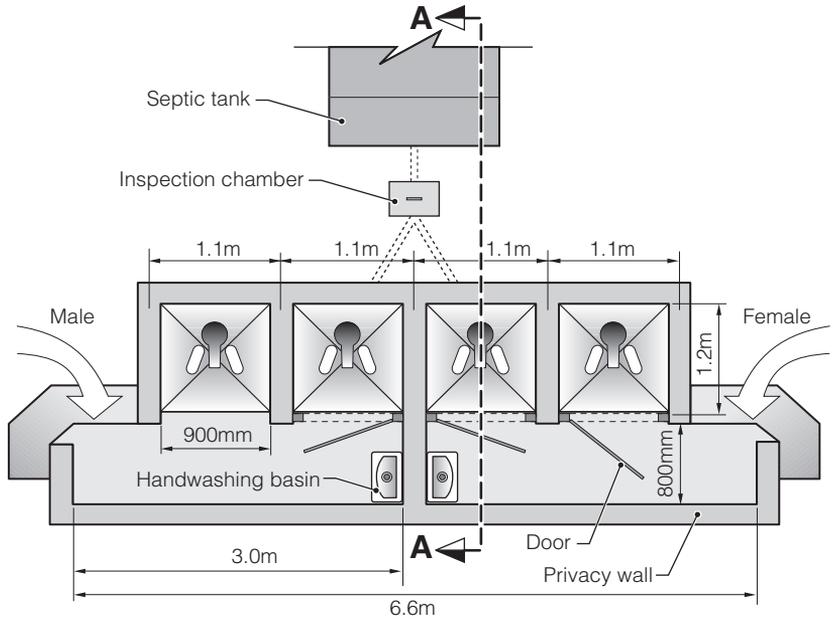
As a first step in developing a latrine design for schools in East Timor, an NGO instigated a consultative process with the Ministry of Education (MoE), the Ministry of Health (MoH), Water Supply and Sanitation (WSS), community leaders such as the aldeia chiefs and headmasters, as well as potential users of the water systems, in order to assess the water and sanitation needs of target schools. Discussions included the project objectives, the respective responsibilities of all stakeholders, the history of each school (including the destruction in 1999), and the community's views on any operational challenges that may be faced during implementation. An operational plan was developed based on these discussions.

Where a school was close to a community, discussions were held with each community and the relevant headmasters regarding the formation of a Water Management Committee (WMC). These meetings focused on the responsibilities expected of the WMCs/headmasters and the difference between the present political and social situation compared to the Indonesian-controlled times. The NGO pledged technical training and organizational support to the WMCs while the community acknowledged their responsibility for the health of their children through the maintenance of the water-supply and sanitation facilities. A commitment to establish WMCs was obtained from these discussions.

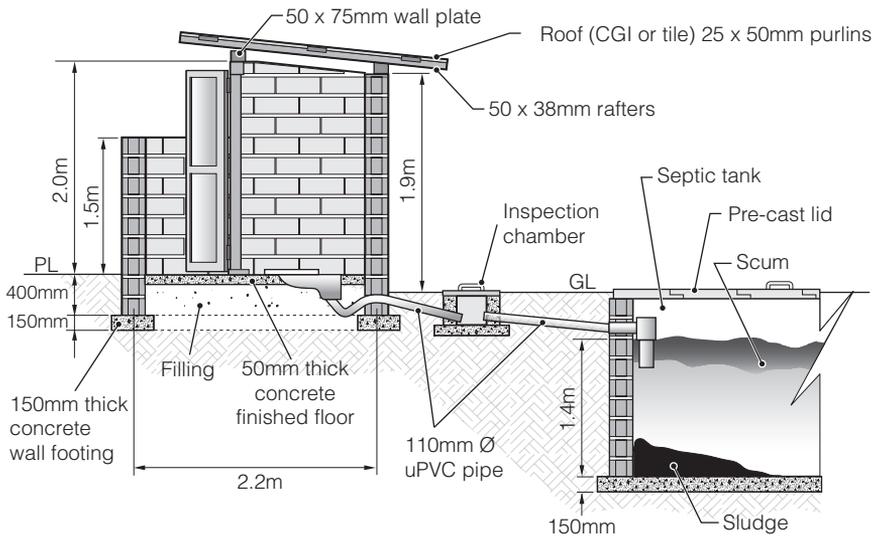
Prior to the construction of facilities, meetings were held between the NGO and community representatives to discuss the most suitable facilities to be installed, as well as the most suitable WMC organizational structure to be established. The responsibilities of each member of the WMC were decided jointly and the WMC formally established with open and transparent proceedings. Community-recognized WMCs were formed to manage and maintain facilities in all communities linked to schools.

*Source: ECHO Final Narrative Report – Water, Sanitation and Hygiene for East Timorese Children, 2001 – 2002*

## EXCRETA DISPOSAL IN EMERGENCIES



**Plan view**



**Section on A-A**

**Figure 5.8. Institutional latrine design**