

Chapter 10

Wastewater management

10

Within the scope of this book, wastewater is considered to mean sullage, i.e. waste water that does not contain excreta or toilet wastes, except those arising from soiled bodies and clothing (Cairncross and Feachem, 1983). Therefore for the purposes of this Chapter, the term wastewater does not include sewage or rainwater.

10.1 Associated risks

Although wastewater may not pose such obvious health risks as excreta or medical waste, there are several indirect risks which should be considered. It is necessary to provide appropriate wastewater management systems in order to:

- minimise breeding grounds for water-related insect vectors (e.g. mosquitoes);
- prevent erosion of shelters and facilities;
- prevent wastewater entering pit latrines or solid waste pits;
- prevent pollution of surface or ground water sources; and
- allow safe access to shelters and facilities.

Inappropriate systems, as well as lack of intervention, can increase some of these risks rather than reduce them. Systems involving standing water may inadvertently increase mosquito populations and infiltration systems may lead to the pollution of groundwater sources.

Although the quality of the wastewater may not pose a direct risk to humans (assuming it is not ingested), where wastewater intercepts excreta or refuse disposal sites the risk of disease transmission can increase greatly. Wastewater which spreads toilet wastes or refuse will also spread the likelihood of direct human contact with disease-causing pathogens. This is especially the case where children play or people bathe in the watercourse into which the wastewater is disposed of.

Wastewater can also pose considerable environmental risks, especially where it carries significant components of oil or detergent-based products, and where final disposal sites become stagnant. For this reason it is sometimes necessary to treat wastewater prior to disposal in the environment (see 10.4).

10.2 Sources and types of wastewater

The most common sources of wastewater are:

- water taps;
- kitchens/feeding centres;
- laundries;
- bathing areas; and
- clinics.

In most refugee camps, water is carried to dwellings. Where this is the case, volumes of domestic wastewater are generally low and well dispersed, and hence do not pose any serious health hazard. It is still important, however, that people are aware of where and where not to dispose of their domestic wastewater.

Where waterpoints are used for water collection only, the volumes of wastewater produced are likely to be low, resulting from the rinsing of collection vessels and spillage only. The rate of wastewater generation will increase greatly where waterpoints are also used for laundry purposes. For this reason, it is recommended that specified laundry areas are provided with disposal systems able to cope with the quantity of wastewater produced.

In general, wastewater has high turbidity and high values of total suspended solids (TSS); it may also contain oils, detergents and food substances. Total and faecal coliforms may sometimes be present, especially where water has been used for laundry purposes.

10.3 Selection criteria

In determining appropriate interventions for wastewater management there are several important factors to consider:

- Ground conditions
- Groundwater level
- Topography
- Location and type of water sources
- Quantity and quality of wastewater generated
- Climatic conditions
- Socio-cultural considerations

10.3.1 Ground conditions

One of the key factors in determining an appropriate technology choice for wastewater disposal is the condition of the ground or soil. Infiltration techniques are often adopted but may not always be appropriate. In some instances, ineffective soakpits may pose higher health risks (e.g. as potential mosquito breeding sites) than no intervention at all.

A soakpit or infiltration trench will only be effective if wastewater is able to percolate into the soil. Section 4.3.2 gives guideline infiltration rates for different types of soil and how to identify these soils. Where there is any doubt concerning whether infiltration will work, it is good practice to determine the approximate permeability of the ground by conducting a simple infiltration test.

10.3.2 Groundwater level

The groundwater level will also influence whether infiltration can be used, and seasonal variations in this must be considered. Where the water table is close to the ground surface, infiltration is likely to be severely limited. Soak pits or infiltration trenches that intercept the water table will fill rapidly and are unlikely to cope with large volumes of wastewater. In addition, the risk of groundwater pollution will increase with the height of the groundwater level.

10.3.3 Location and type of water sources

In all cases, it should be a priority to prevent contamination of clean drinking-water sources with wastewater. It is therefore important that the locations of all existing, or potential, water supply sources are taken into account when selecting and designing wastewater management systems. Conversely, drainage possibilities should be considered when selecting and designing water distribution points.

Where wastewater is discharged into surface waters, it is important that this is downstream of any water supply intakes. This will prevent increased water treatment requirements. It is also important to consider downstream water use and what the effects of effluent discharge will have on this.

Where groundwater is used as a water source, several factors should be considered if wastewater is disposed of by infiltration. Although the ground will act as a filter and remove impurities as the wastewater travels to the aquifer, the following safety measures should be taken:

- Soakpits or infiltration trenches should be at least 30m horizontal distance from any groundwater source (e.g. well, borehole).
- Disposal sites should be downhill of groundwater sources where possible.
- The base of any soakpit should be at least 1.5m above the water table.
- Where wastewater contains a high oil component, water should be treated prior to disposal.

10.3.4 Topography

The topography of the affected site will be a key factor in determining whether surface drainage techniques can be adopted. It is rare to find a site that is completely flat, although where this is the case, or nearly so, surface drainage becomes almost impossible. In general, a minimum gradient of 1 in 200 is recommended for the transport of wastewater in earth drainage ditches (Davis and Lambert, 1995). Where drainage channels have to circumnavigate natural obstacles, such as mounds or hillocks, this may increase labour time and costs considerably.

10.3.5 Quantity and quality of wastewater generated

The volume of wastewater generated will also influence the technology choice made. Where there are only small quantities of wastewater, infiltration may be appropriate even in low-permeability soils, or these may be removed rapidly through evaporation. Where larger volumes are involved, disposal systems must be selected and sized accordingly. Existing systems may become inappropriate if water use increases greatly, and will need upgrading or replacing. Guideline wastewater generation rates for public institutions are as follows:

EMERGENCY SANITATION

- Field hospital: 55 litres/person/day
- Cholera treatment centre: 100 litres/person/day
- Feeding centre: 25 litres/person/day
- Out-patients clinic: 100 litres/day (total)

Whilst the quality of wastewater is not of major importance in most cases, with low numbers of pathogens, this should also be considered. Wastewater from water collection points is unlikely to require treatment, whilst that from kitchens or hospitals probably will.

10.3.6 Climatic conditions

Climatic conditions will also affect intervention selection. In hot, dry climates evaporation or irrigation use of wastewater may be viable. In wetter climates the volume of rainfall must be considered, and may even be used in removing wastewater.

In colder climates the possibility of drainage pipes or systems freezing should not be overlooked.

10.3.7 Socio-cultural considerations

Although wastewater management in general is a less sensitive issue than excreta disposal or hygiene promotion, socio-cultural aspects should also be considered. Where surface drainage channels pass through residential areas this may create temptation for people to use wastewater for domestic purposes, and it may be difficult to deter them from doing so.

Cultural practice and tradition, in terms of water use, may also influence the volume of water used and wastewater generated. This may also affect when wastewater is produced, for example if large numbers of people bathe or do laundry at a particular time of day.

10.4 Technology choice

The immediate action options for wastewater management are generally the same as those for longer term intervention. It may be appropriate, however, to implement a simple option in the emergency phase and develop this further at a later date. Whenever possible, wastewater should be disposed of close to the point of origin. The simplest method, where possible, is to divert wastewater to local watercourses. The most common method in emergency situations is probably infiltration. The technology choices included here are:

- Soakaways or soakpits
- Diversion to natural drainage
- Diversion to man-made drainage
- Infiltration trenches
- Bucket basins
- Evaporation pans
- Evapotranspiration beds
- Irrigation use

WASTEWATER MANAGEMENT

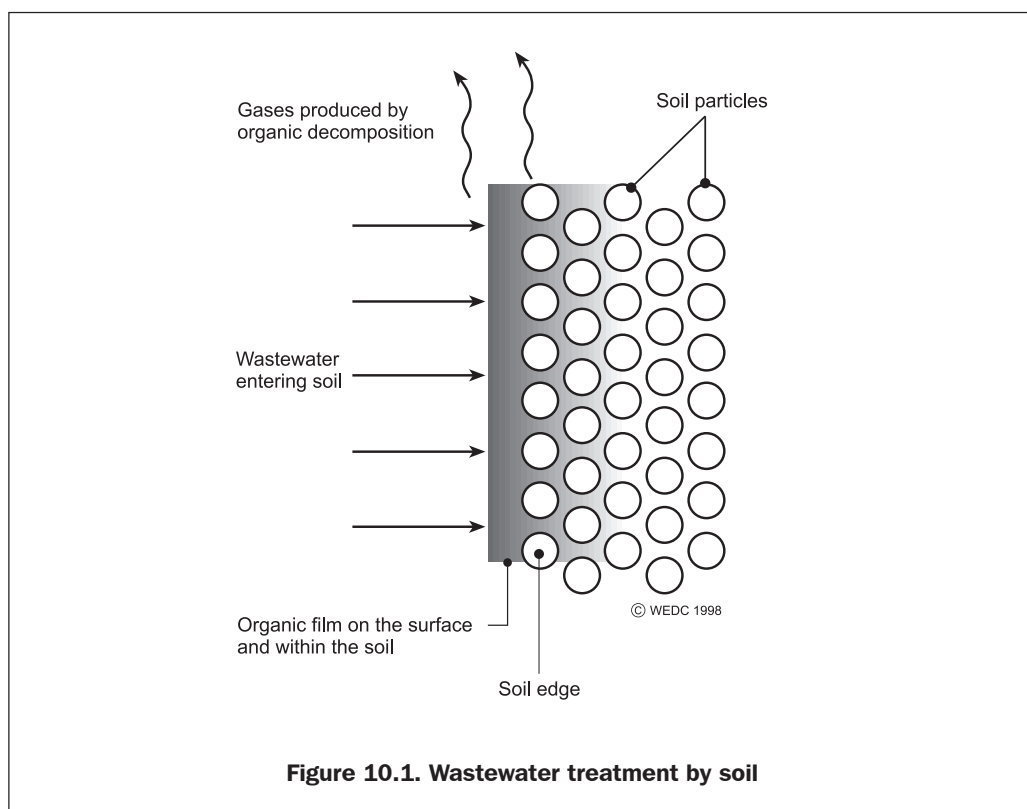
10.4.1 Soakpits

A soakpit, or soakaway, is simply an excavation in the ground which facilitates the percolation of wastewater into the surrounding soil. As well as wastewater from the sources outlined above, a soakpit can also be used to dispose of the effluent from a septic tank or aquaprivy. By spreading the effluent over a sufficiently large soil area the water is treated and absorbed efficiently. Depending on the wastewater quality, a film of organic slime may develop on the walls of the soakpit and just inside the soil (Figure 10.1). As the wastewater passes through the slime it traps suspended particles and the organisms which live in the slime feed off the waste products in the effluent. If the flow is too high, the slime layer will grow until it completely blocks the soil, preventing any further flow of wastewater.

The treatment process is much more efficient if the soil is kept well oxygenated. This requires the soil to be alternately saturated with effluent and dried to allow the entry of air. In well-designed systems this happens naturally because of the daily variations in flow. The process is far less efficient in constantly saturated conditions such as below the water table.

Whether a soakpit will function or not depends primarily on the permeability of the soil. Soil pores may become clogged with time and this can reduce the infiltration capacity of a particular soakpit. Seasonal variations in the water table can also affect the performance greatly, and a soakpit which works perfectly in the dry season may overflow at other times of year.

10



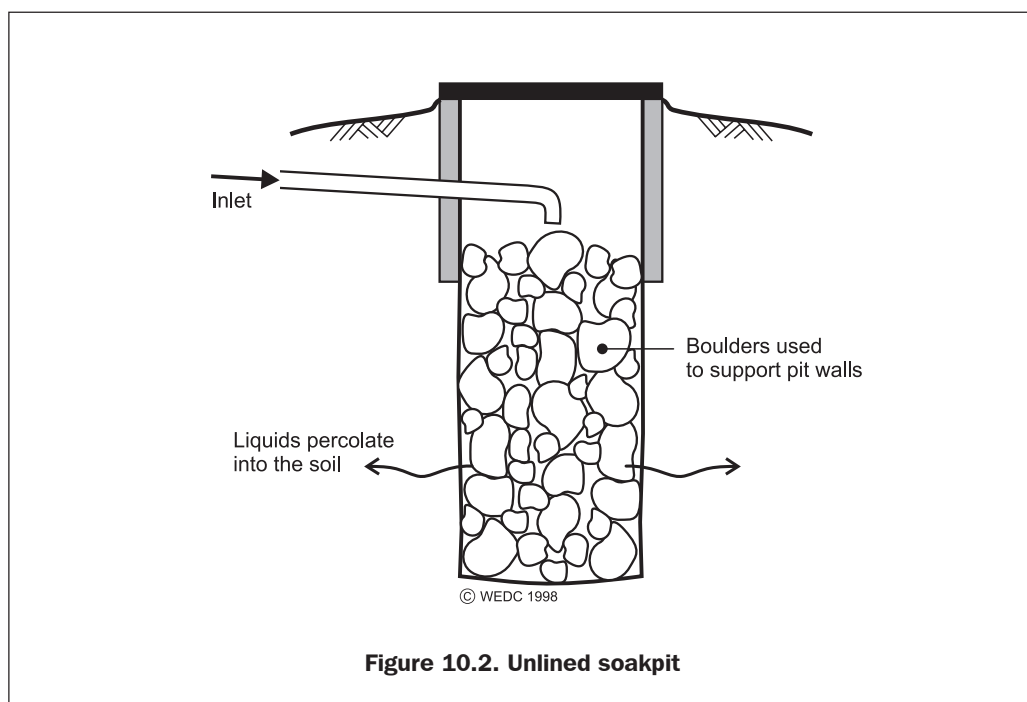
EMERGENCY SANITATION

Soakpits are commonly between 2 and 5m deep and 1 to 2.5m in diameter. Wastewater entering the pit may soak into the surrounding soil through the sides and base of the pit. If the water has a high solids content, however, the base of the pit will quickly become blocked with silt and sludge. Where this occurs infiltration will only take place through the pit walls, therefore the base area is ignored when designing soakpits.

Most pits in emergency situations are not lined but filled with large stones, blocks, bricks, etc. (Figure 10.2). This fill is to support the pit walls and the cover. It does not play any part in the treatment of wastewater and its volume should be deducted when calculating pit volumes.

Advantages: Soakpits are easy and relatively quick to construct; and can be used on flat sites.

Constraints: They are only appropriate in permeable ground conditions; and can only cope with a limited volume of wastewater.



WASTEWATER MANAGEMENT

Alternatively, the pit can be lined (Figure 10.3). Any lining must be porous so that the wastewater can reach the soil surface. The top 0.5m of any pit must have a sealed lining in order to prevent the infiltration of rainwater.

The size of a soakpit depends on the volume of liquid to be disposed of and the type of soil in which the pit is excavated. It may be calculated by using the following process:

1. Calculate the surface area of pit wall required for infiltrating the wastewater:

$$\text{Pit wall area (m}^2\text{)} = \text{daily wastewater flow (litres)} \div \text{soil infiltration rate (Table 4.3)}$$
2. Choose a pit diameter.
3. Calculate the depth of pit required to dispose of all the liquids:

$$\text{Depth of pit required} = \text{pit wall area} \div (\pi \times \text{pit diameter})$$
4. Add 0.5m (lined depth) to calculate the total pit depth needed.

10

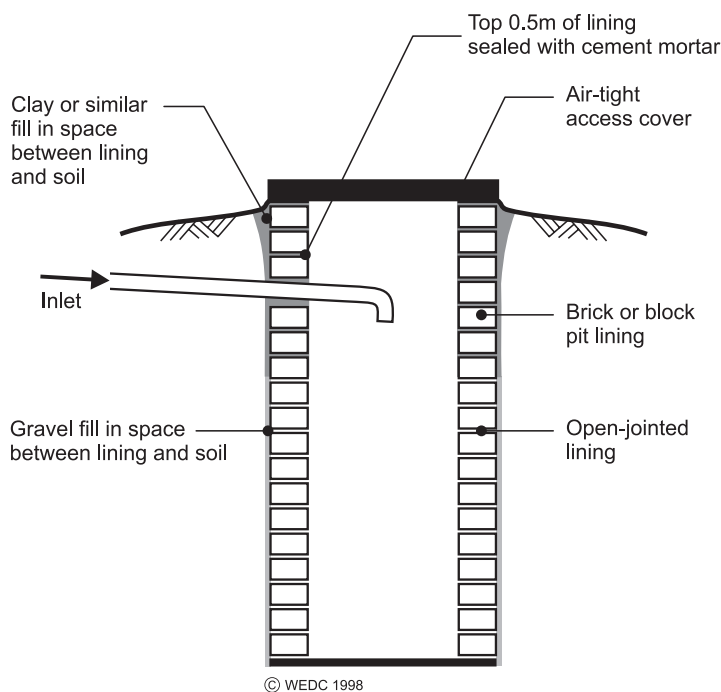


Figure 10.3. Soakpit lined

EMERGENCY SANITATION

Worked example: A soakpit is required to dispose of 500 litres per day in a sandy loam soil (infiltration rate = 25 litres/m²/day: see Table 4.3). There is space for a pit of 2m diameter only.

Pit wall area = wastewater flow ÷ infiltration rate = $500 \div 25 = 20\text{m}^2$

Depth of pit = pit wall area ÷ (p x pit diameter) = $20 \div 2\pi = 3.2\text{m}$

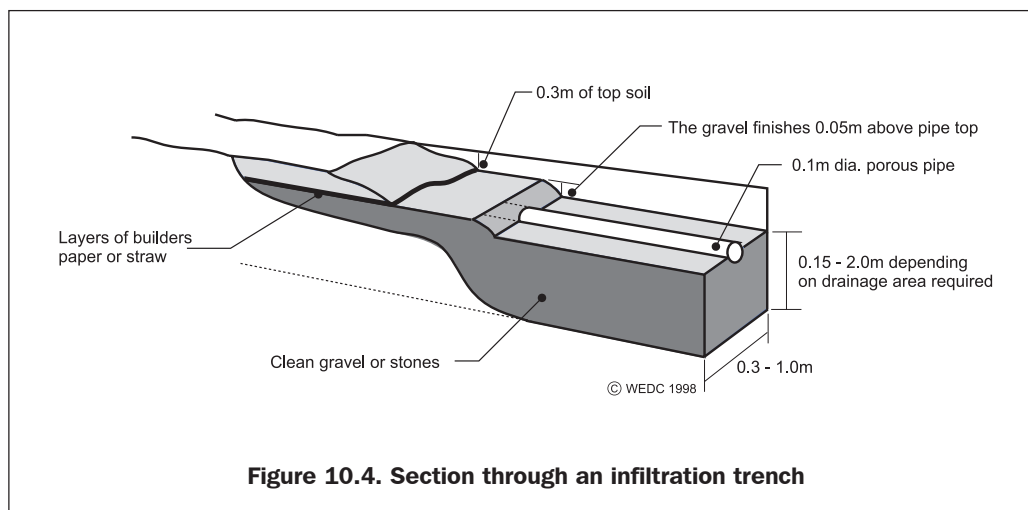
Total depth of pit = depth of pit + 0.5m = $3.2 + 0.5 = 3.7\text{m}$

Note: Wastewater from large institutions, such as hospitals, is likely to be far too great in volume to be disposed of in a single soakpit.



Poorly designed soakpit, Tanzania

WASTEWATER MANAGEMENT



10.4.2 Infiltration trenches

An infiltration trench is a variation on a soakpit. Its advantages are that it provides a higher surface area for the volume of soil excavated, and it uses the upper soil layers which tend to be more porous. Instead of directly entering a pit, the wastewater is dispersed by pipes along a series of trenches that have been filled with coarse gravel (Figure 10.4).

The pipes are porous so that the wastewater can seep out into the surrounding gravel, and from there, through the walls of the trench into the soil. Pipes can be made from porous materials such as concrete made without sand, or small holes or slots can be cut in the walls. Pipes are laid horizontally to allow the water to be distributed evenly along the whole length. The size of the pipe depends on the volume of flow but for most situations 100mm diameter is sufficient.

The top of the pipe is covered with a layer of paper, straw or porous plastic sheeting. This allows air to enter the trench and gases to escape but prevents the topsoil from mixing with the gravel and blocking the trench.

Trenches should be as narrow as possible since it is only the side walls that absorb the effluent. Generally the trench should be 300-600mm wide, and a depth of about 1m below the bottom of the distribution pipe.

Advantages: Trenches are easy and relatively quick to construct; can be used on flat sites; and can cope with a greater amount of wastewater than a soakpit of the same volume.

Constraints: They are only appropriate in permeable ground conditions.

EMERGENCY SANITATION

The length of an infiltration trench can be calculated by using the following process:

1. Calculate the surface area of trench wall required for infiltrating the wastewater:
Infiltration area (m²) = daily wastewater flow (litres) ÷ soil infiltration rate
2. Calculate the total length of side wall required:
Total length of side wall = infiltration area ÷ trench depth below distribution pipe
3. The length of trench required is half of the total length of side wall.

Note: Ideally, the infiltration rate should be measured at a number of places in the drainage area, since soil texture changes very quickly. Details of how to do this can be found in Chapter 4.

10.4.3 Natural drainage

If natural drainage can be used to dispose of wastewater to flowing streams or rivers then this should be used. Care must be taken to ensure that this occurs downstream of water sources, and in general a slope of at least 1 in 200 is required for water to drain effectively in earth channels. Lined drainage channels (e.g. concrete) are likely to be effective on lesser slopes, but are costly and time consuming to construct, and unsuitable in most emergency situations.

Wastewater with high organic content, including laundry wastewater, should not be diverted to stagnant ponds, where it may become anaerobic and offensive. Discharging large volumes of wastewater to small watercourses may also cause periodic overflowing, leading to pooling of stagnant water.

Advantages: A minimal amount of construction work is required; and there are negligible physical effects on landscape.

Constraints: It is rarely possible; and may inadvertently pollute watercourses.

10.4.4 Man-made drainage

In some sites it may be appropriate to construct drainage channels cutting through natural obstacles, such as earth mounds or hillocks, to reach an existing water course. This is likely to be arduous work, expensive and time consuming. However, it may be the only option where infiltration is impossible and where natural drainage leads to stagnant or hazardous conditions.

Advantages: It may be the only option in impermeable sites with small gradients.

Constraints: It is expensive and time consuming to construct; and may have a large impact on the surrounding landscape.

WASTEWATER MANAGEMENT

10.4.5 Evaporation pans

An evaporation pan is a shallow pond which holds water and allows it to evaporate (Figure 10.5). Evaporation rates depend upon solar radiation, temperature, humidity and windspeed. Wastewater can be disposed of to evaporation pans in hot, dry conditions where evaporation rates considerably exceed rainfall rates for the operating period.

In general, large areas of land are required for evaporation pans to work successfully. Even a high evaporation rate of 5mm/day requires a surface area of 200m² per cubic metre of liquid per day (Davis and Lambert, 1996). Assuming that there is no infiltration of water into the soil, the area required can be estimated by using the following equation:

$$\text{Area (m}^2\text{)} = \frac{\text{Volume of wastewater per day (m}^3\text{)} \times 1000}{\text{Evaporation rate (mm/day)}}$$

Evaporation rates are difficult to determine and meteorological instruments are required. Measuring direct evaporation of water from an evaporimeter is the simplest method although this still requires the collection of additional rainfall data. Alternatively, evaporation can be estimated mathematically from measured climatic factors (i.e. air temperature, humidity, sunshine and windspeed). Information regarding how to conduct such measurements is contained in most field hydrology textbooks but the best solution is to obtain data from nearby weather stations (where possible). In general, evaporation pans should only be used for wastewater disposal where there is a mean evaporation rate of at least 4mm/day, where rainfall is negligible and where there is no viable alternative.

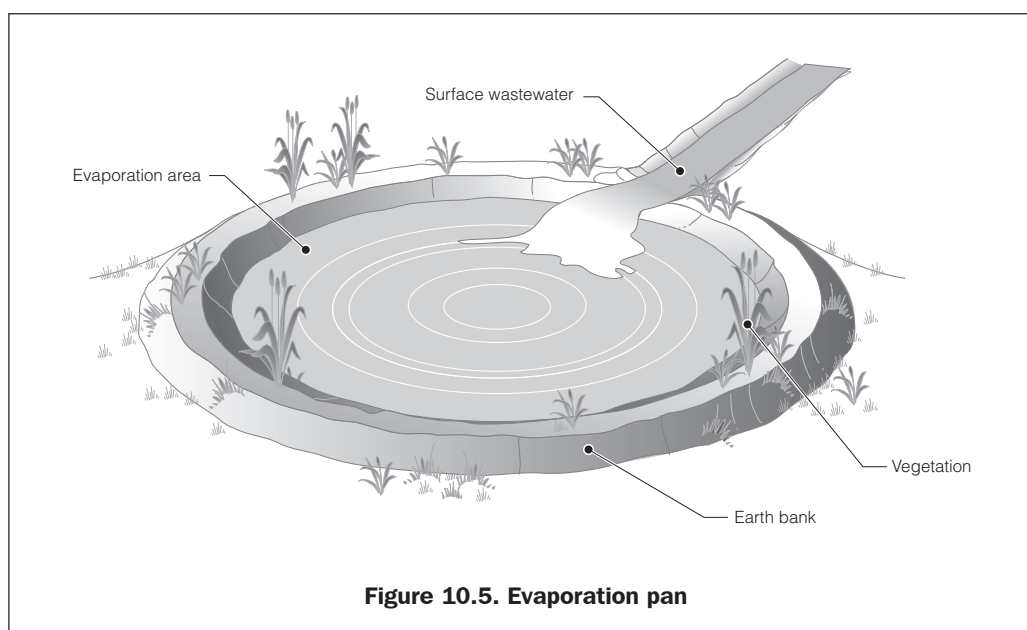


Figure 10.5. Evaporation pan

EMERGENCY SANITATION

Pans should be sited far away from habitation to limit water-related insect hazards (e.g. mosquitoes) and require careful management if they are to be effective. Provision will need to be made for managing possible overflow during periods of rainfall and regular maintenance is likely to be necessary.

Advantages: Evaporation pans are suitable in arid conditions where other disposal methods, such as infiltration, are inappropriate.

Constraints: They may encourage mosquitoes, flies, etc; and large areas are required.

10.4.6 Evaporation and evapotranspiration beds

Evaporation beds can be used where infiltration methods cannot, but are only suited to dry, arid climates. This method relies on capillary action to draw water to the surface of shallow sand beds, where it is evaporated to the atmosphere. An improvement on this is the evapotranspiration bed (Figure 10.6) which increases the rate of water removal by planting vegetation in the bed to draw up water and encourage transpiration.

Solid materials should be removed from wastewater before it is allowed to enter the sand bed through a system of distribution pipes. The perforated pipes should be about 1m apart and surrounded by uniform-sized gravel or stone (typically 20-50mm diameter). A permeable filter cloth is placed over the gravel, and the bed is filled with sand and covered with a layer of topsoil in which grass is planted. To keep beds aerobic and prevent clogging they should be as shallow as possible, and not more than 1m deep.

The size of an evapotranspiration bed will depend on local evapotranspiration and rainfall rates (available from nearby weather stations), and daily wastewater flow (or loading rate). Loading rates of up to 10 litres/m²/day can be applied, although performance will depend on soil type, vegetation, wind speed, humidity, solar radiation and temperature. Any rainfall runoff should be diverted around the system.

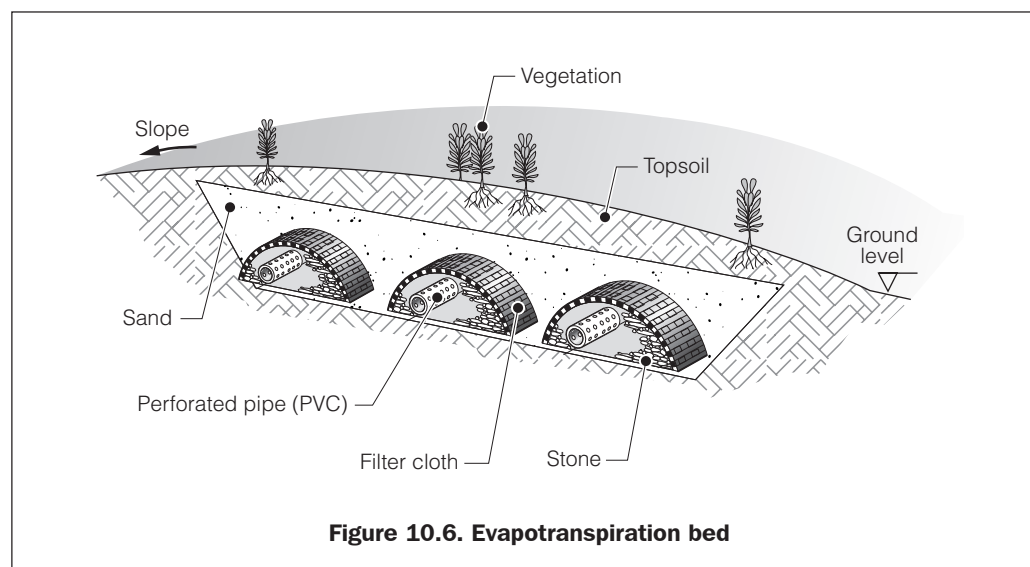


Figure 10.6. Evapotranspiration bed

WASTEWATER MANAGEMENT

Advantages: These beds are suitable in arid conditions where other disposal methods are inappropriate.

Constraints: Careful management is required; and the beds can only cope with a limited volume of wastewater.

10.4.7 Irrigation

Where large volumes of wastewater are generated it may be appropriate to make use of this for small-scale irrigation. This may simply consist of planting fast-growing fruit trees, such as papaya or banana, in the drainage channels. Alternatively, drainage channels may be used to divert the flow to small areas of arable land which may be deliberately flooded with wastewater to promote plant growth.

In general, wastewater cannot be used for large-scale irrigation and careful monitoring should occur to ensure that clean drinking water is not diverted for irrigation use, especially where there is a limited water supply.

Advantages: Irrigation can make use of large volumes of water; and contributes to agricultural activity in the affected area.

Constraints: In general, small-scale possibilities only are viable; and it may encourage inappropriate use of drinking water.

10.5 Wastewater treatment

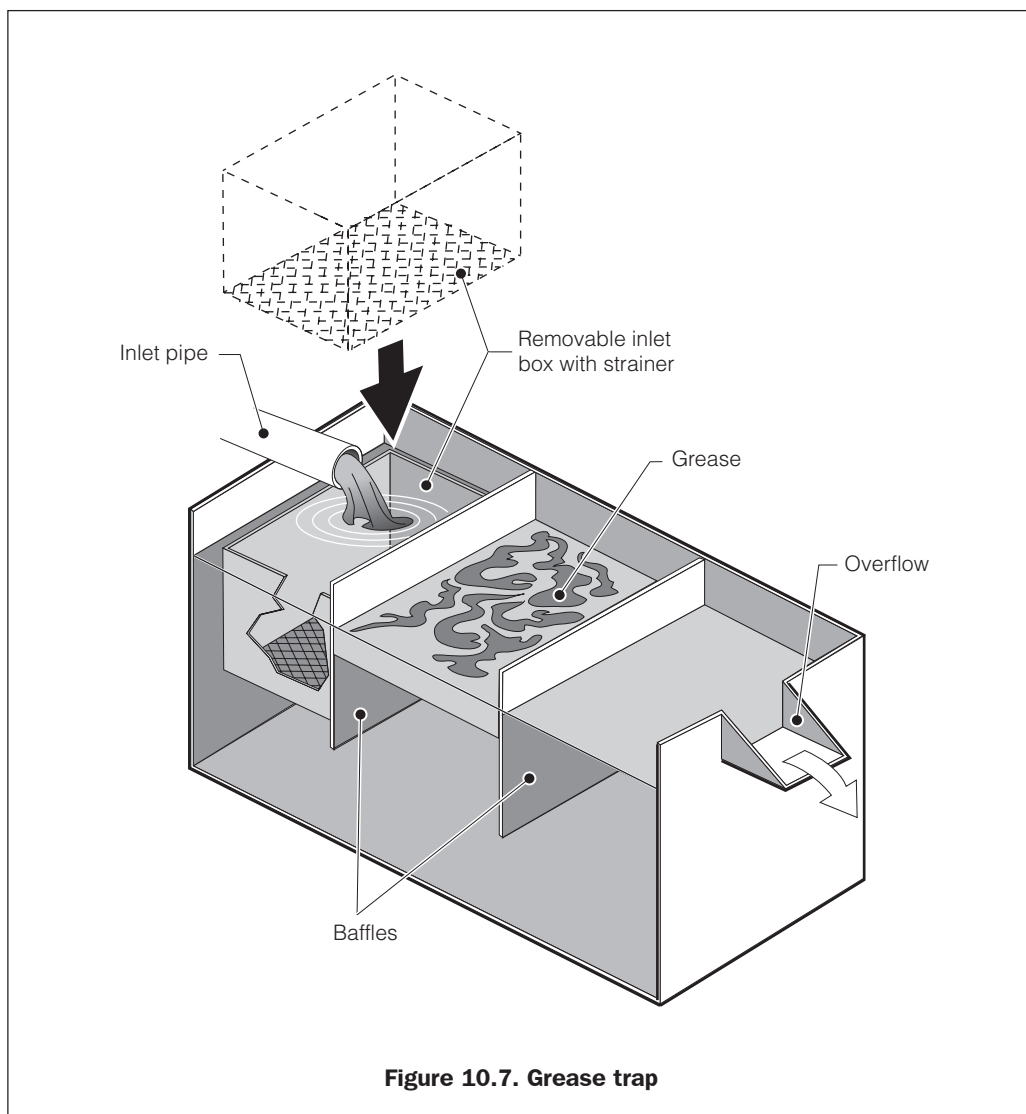
Although many of the methods outlined above involve some treatment as well as simple disposal of wastewater, it is sometimes necessary to implement additional treatment facilities. Where wastewater has high solids, oil or detergent content it will be necessary to separate these components prior to disposal. This is likely to be especially appropriate for wastewater from kitchens or feeding centres catering for large populations.

10.5.1 Solids removal

Wastewater with a high solids content should be strained, especially if infiltration techniques are to be used. This will prevent soil pores from quickly becoming clogged and preventing infiltration. A simple method of solids removal is to pass the wastewater through a woven sacking strainer. Alternatively a crude plastic filter may be made by cutting small slots in the base of a plastic bucket. These should regularly be inspected and cleaned as required.

10.5.2 Grease traps

A grease trap, as the name suggests, is designed to trap grease or oil and allow treated wastewater out. This should be sited upstream of the final disposal system. A simple grease trap (Figure 10.7) consists of an inlet with a strainer to remove solids, and a series of baffles. These baffles are designed to trap grease, which floats to the liquid's surface, so that only clean water travels underneath and eventually out through the overflow. Grease traps should be emptied of grease at regular intervals, preferably daily. Traps can be built from bricks, blocks, wood or an oil drum cut in half along its longest axis.



10.5.3 Settlement tanks

A more sophisticated version of the grease trap is a settlement tank (Figure 10.8). This works on the same principle to trap grease or 'scum' on the liquid surface and also allows suspended solids to settle forming a sludge deposit on the base of the tank.

The outflow from the tank should go to a soakage pit or trench, or a nearby watercourse. The settled material in the tank should be removed and buried when the tank is about one-third full of solids. Table 10.1 indicates appropriate settlement tank sizes for different flow rates (see 10.3.5 for guideline flow rates).

WASTEWATER MANAGEMENT

Table 10.1. Sizes of settlement tanks

Inflow rate (litres/day)	Liquid depth ^a (m)	Tank length ^b (m)	Tank width (m)
2000	1.2	1.9	1.0
5000	1.4	2.8	1.4
10000	1.5	3.3	1.7
15000	1.5	3.4	1.7
20000	1.5	4.0	2.0

- a Allow 30cm extra tank depth above liquid level
- b First compartment twice the length of second

These sizes assume that the solids will be removed from the tank every three months. Where the system is to become permanent, a larger tank may be constructed which needs emptying less often.

10

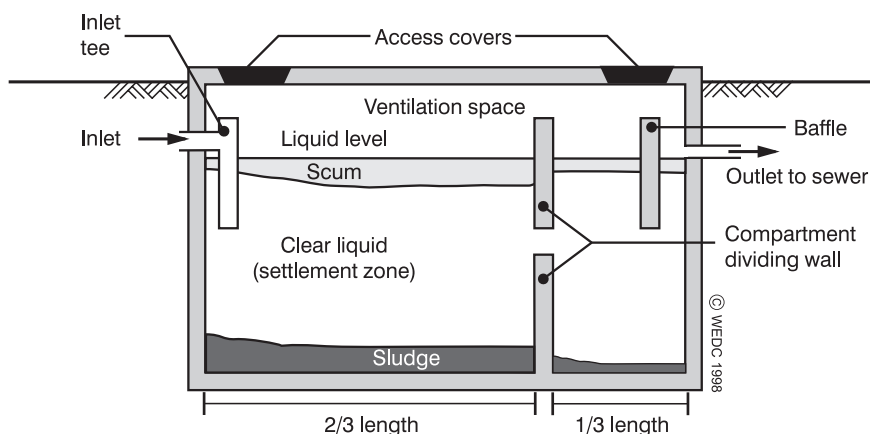
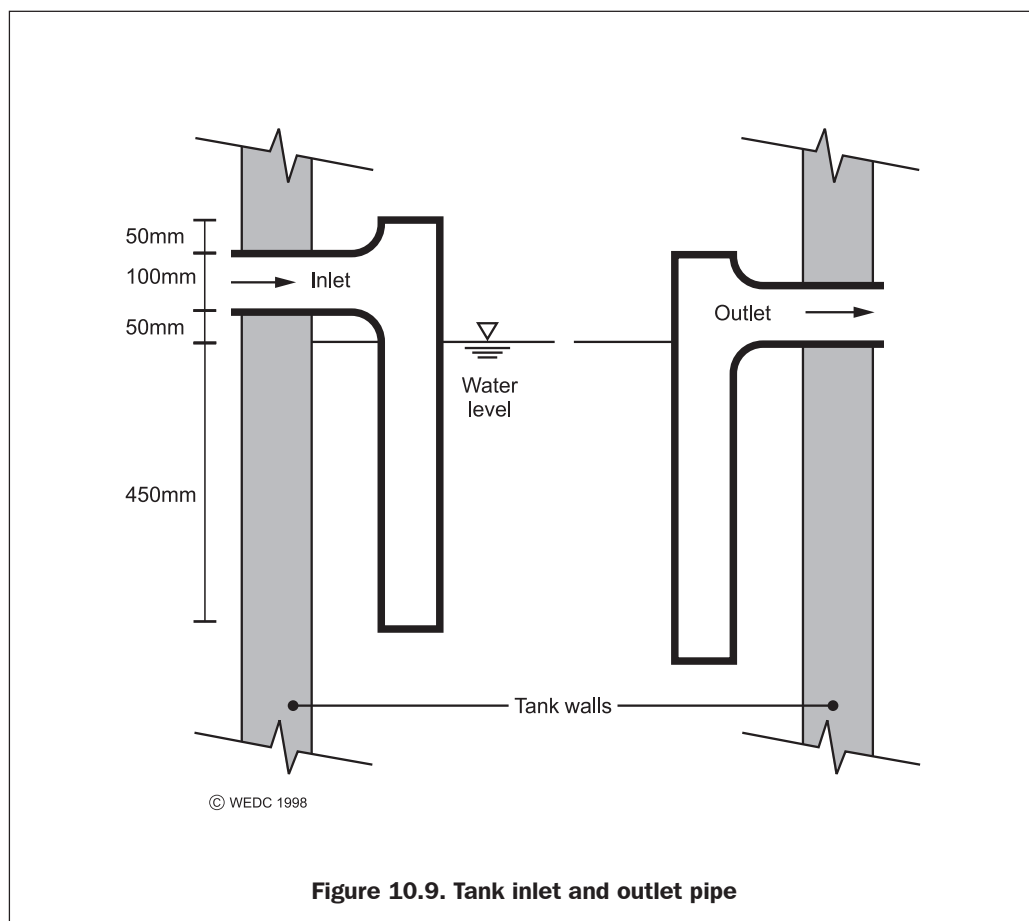


Figure 10.8. Settlement tank

Settlement tanks may be constructed above or below the ground. The tank walls can be built from concrete, bricks, timber or earth. The tank should have a minimum depth of 1.2m to allow adequate settling, and at least 0.3m between the liquid surface and the base of the cover for ventilation. The inlet and outlet may be made using a 'tee' piece (Figure 10.9), or for larger units a weir may be used for the outlet.



10.5.4 Septic tanks

In a large public institution such as a hospital or medical centre septic tanks can also be used for disposal of wastewater from kitchen, laundry and washing facilities. This dilutes the effluent from toilets and can be used for treating both sewage and grey wastewater (see Section 6.8.10 for design details).

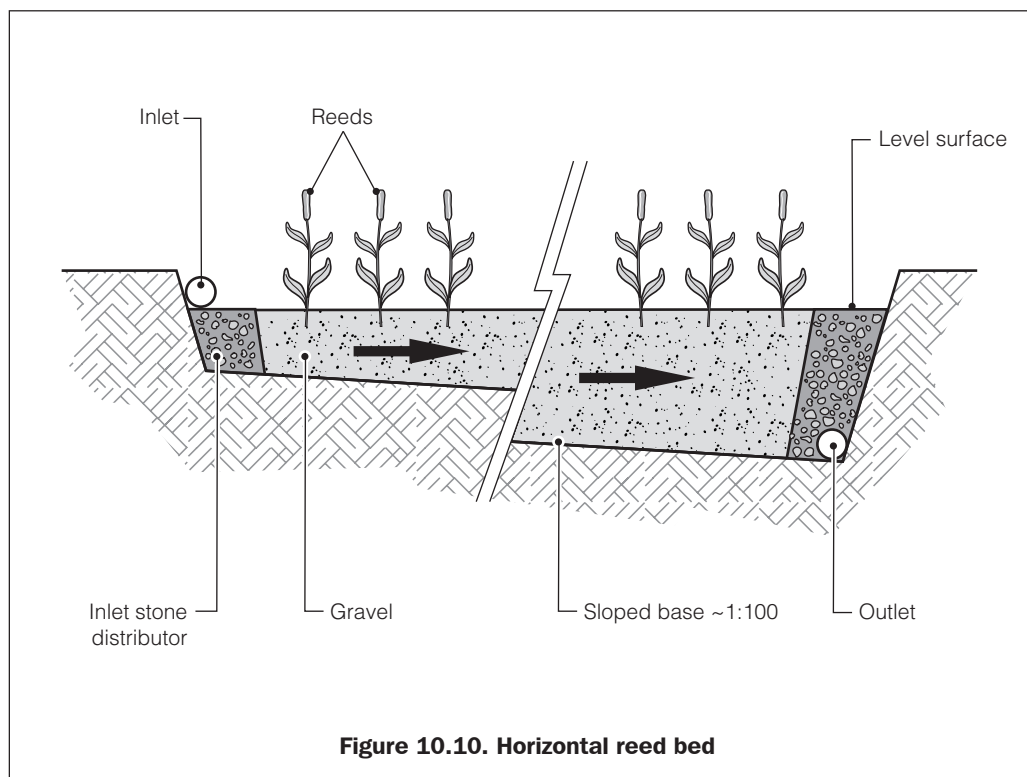
10.5.5 Reed beds

Man-made reed beds (or constructed wetlands) treat wastewater by removing organic matter, oxidising ammonia, reducing nitrate and removing phosphorous (Cooper et al., 1996). Reed

WASTEWATER MANAGEMENT

beds can be used to treat sewage effluent as well as sullage and generally consist of a gravel-filled bed covered with a layer of soil or sand in which reeds are planted. Once treated the water can be discharged to a natural watercourse. There are two main types of bed, either vertical flow or horizontal flow.

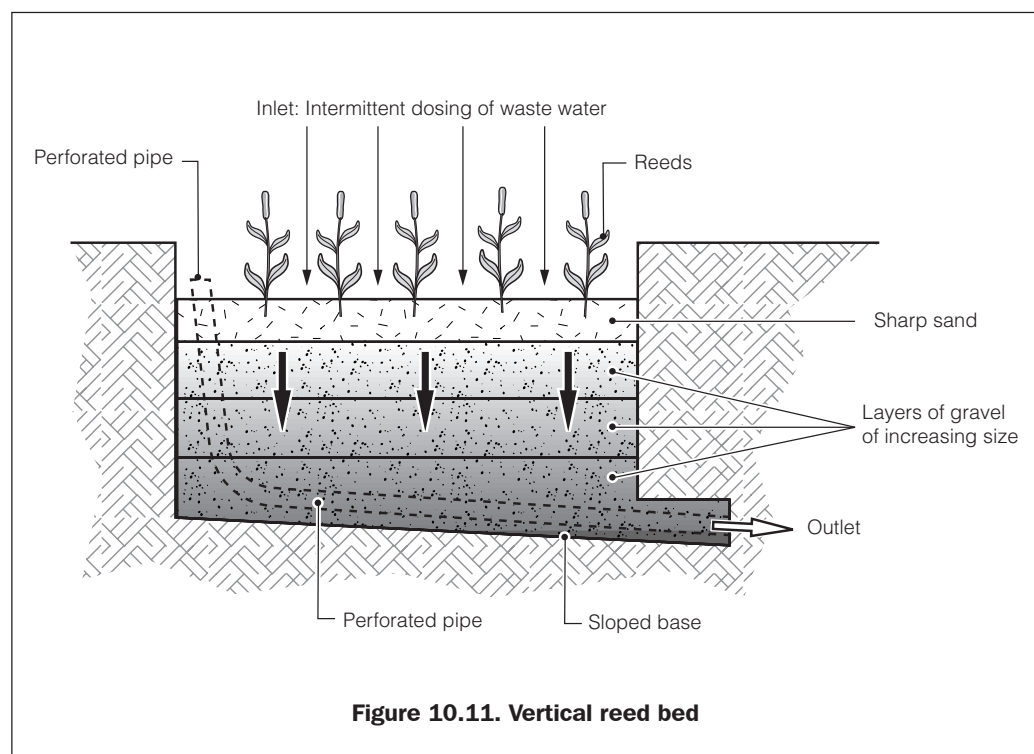
Figure 10.10 shows a horizontal reed bed where wastewater is fed into the bed via an inlet stone distributor (resembling a small soak pit). Wastewater flows horizontally from the distributor at one end of the bed to an outlet at the other. A 30-50cm depth of water should be maintained in the bed. Horizontal flow beds are simple to operate and maintain but take up more land area than vertical flow beds.



EMERGENCY SANITATION

Vertical flow reed beds allow wastewater to trickle down through the bed media as illustrated in Figure 10.11. Here the wastewater must be introduced to the system in batches so that the bed is completely flooded for a while and is then allowed to drain. This allows air to be trapped in the soil and the extra oxygen results in more effective removal of nitrogen compounds and phosphates from the wastewater (Smith, 2001). Vertical flow beds require more intensive management than horizontal beds and a secondary system for holding back each batch of wastewater is required.

Reed bed systems must be carefully sized (see Cooper et al., 1996) and inlet troughs and pipes should be cleaned at monthly intervals to prevent blockages.



10.6 Cholera treatment centres

Wastewater from medical installations dealing with specific epidemics, such as cholera treatment centres, should have independent wastewater management systems. It is important that any infection is contained and that the spread of epidemic is minimised. Large waste volumes of chlorine-based disinfectants are also likely to be produced in such cases, since these are used to wash down facilities and equipment. In general, such installations should have their own septic tank and underground disposal (e.g. soakpit) isolated from both ground and surface water sources.

10.7 Rainfall runoff

Although this book is not dealing with site drainage specifically, it is important that this is considered, especially in areas of high rainfall. Drainage of rainfall runoff may be essential to prevent erosion of soil and soil-based buildings, to allow safe access and movement around the site, and to minimise areas of standing water. It is also important that sanitation facilities such as pit latrines, refuse pits and soakpits are designed so as not to fill with rainwater following heavy rainfall, in order to prevent the spread of disease.

In general, drainage channels should be constructed to ensure that the site does not become a swamp every time it rains. These channels may also be used to dispose of wastewater which may be diluted with rainwater. All drainage facilities must be adequately maintained, and regular inspection and cleaning should be conducted.

References and further reading

- Adams, John (1999) *Managing Water Supply and Sanitation in Emergencies*. Oxfam: Oxford.
- Ayoade, J.O. (1988) *Tropical Hydrology and Water Resources*. Macmillan Publishers: Basingstoke & London.
- Cairncross, S. and Feachem, R. (1983) *Environmental Health Engineering in the Tropics: An introductory text*. John Wiley & Sons: Chichester.
- Cooper, P.F., Job, G.D., Green, M.B. and Shutes, R.B.E. (1996) *Reed Beds and Constructed Wetlands for Wastewater Treatment*. WRC: Swindon.
- Davis, Jan and Lambert, Robert (1996) *Engineering in Emergencies: A practical guide for relief workers*. RedR / IT Publications: London.
- Médecins Sans Frontières (1994) *Public Health Engineering in Emergency Situation*. Médecins Sans Frontières: Paris.
- Reed, R. and Dean, P.T. (1994) Recommended Methods for the Disposal of Sanitary Wastes from Temporary Field Medical Facilities. *Disasters* Vol 18, No 4.
- Smith, Mike (2001) *Wastewater Treatment: A postgraduate distance learning module*. WEDC, Loughborough University: UK.

