RURAL SANITATION FOR DEVELOPING COUNTRIES

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1 INTRODUCTION

The generally poor health endured by large sections of poor communities is largely due to diseases carried by contaminated food and water. Enteric diseases spread by insanitary disposal of excreta and a polluted water supply are a major cause of illness and death in the developing countries, particularly among children [WHO reports (1), (2)].

Improved sanitation is an important element in the fight against these diseases, but waterborne sanitation systems based on the technology of developed countries are very costly and require extensive water resources.

The development of low cost systems using little water is therefore a high priority and this paper reviews the current state of knowledge and indicates criteria to be applied in design.

The objectives of sanitation technology for the disposal of human wastes can be summarised as: 'providing means of collecting, retaining and rendering excreta harmless and inoffensive before discharge to the environment'.

On-site retention and treatment of excreta in a simple household pit latrine, for example, can be a very effective and low-cost system if proper care is exercised in initial design, construction, hygienic use and maintenance.

2 CRITERIA FOR SANITATION SYSTEMS

The ideal basic requirements for satisfactory excreta disposal systems should ensure:

(a) no unacceptable contamination of ground water that may pollute springs or wells

(b) no unacceptable contamination of surface water

(c) no unacceptable contamination of surface soil

(d) no contact by humans with waste materials within the system

(e) no access to the waste materials for insects or animals

(f) no offensive odours

(g) that the design will cater for modesty needs and personal cleansing practices of users

(h) that the system will be simple and inexpensive to construct, use and maintain.

In developing countries installations very often fall a long way short of these desirable objectives, due mainly to very limited resources but also to a lack of understanding of health hazards by the community itself. However, existing technology for simple low-cost disposal systems can provide the required safeguards to health and the environment which should be the aims of all communities.

3 SANITATION SYSTEMS IN GENERAL USE

Sanitation systems in general use are described below, with a summary of the advantages and disadvantages. In Table 1 a range of systems are compared for location suitability, cost, technology levels, water needs, health and nuisance risks. For further information see references (3), (4) and (5).

3.1 **Bucket latrine or nightsoil bucket.** Consists simply of a privy with seat or squatting plate positioned directly over a bucket or suitable container, which has to be emptied frequently, emptying at night is a general practice. Water is not used for flushing and since the volume of waste is kept to a minimum because of the need to empty the bucket manually, the disposal of other waste materials, such as vegetable refuse and washing waste water, is not practicable by this system. The system attracts flies to the latrine and along the conveyance route to the disposal site; odour nuisance can be extreme and there are obvious health hazards through possible contact with raw excreta. Not necessarily a cheap system in the long run since the emptying service usually has to be paid for. In some parts of Asia the system is used to produce manure for agriculture. As a health protection measure, excreta should be composted to destroy harmful organisms before spreading on the land, as in the Indore process developed in India (6).

3.2 **Overhung latrines.** Simply a privy built over and discharging directly into water, either river or sea. There are important pollution hazards to be considered, particularly the proximity of human habitation and the other uses for the receiving waters, such as community water supply. The system produces little odour or fly nuisance and costs very little to construct. Generally not a recommended system for community use.

3.3 **Pit privy.** Figures 1 and 2. The pit privy is widely used all over the world and consists essentially of a pit in the ground that retains excreta which are digested and eventually made harmless. The privy with either seat or squatting plate is built directly over a pit, generally around 1 m diameter or square and at least 2 m deep; the pit should be in permeable soil to allow slow seepage away of liquids. Unsuitable soil conditions are those that are impermeable, not absorbing liquids, and soils that are too permeable, such as coarse gravel and fissured rock which can allow rapid movement of liquids through the ground, allowing bacterial pollution to travel considerable distances. Pits should be designed for a life of at least four years, preferably 10 years or more, and should be lined near the top to prevent caving in under the weight of the superstructure. When it is full to within 500 mm of the ground surface, the pit should be closed and topped up with soil. A new pit can then be dug nearby if there is sufficient space and the superstructure moved or rebuilt over it. The material in the old pit will have been digested and after about twelve months could be used as soil fertiliser; the emptied pit can then be used again.

Double pit systems are to be preferred, pits being filled and emptied alternatively but sharing a common superstructure. In this way the digging of new pits is obviated, although how the filled pits will be emptied must be considered.

Adequate ventilation of pits should be provided to reduce unpleasant odours by means of a black painted pipe, at least 100 mm dia and capped with a fly screen, situated on the sunny side of the superstructure. The warmed pipe will encourage air to be drawn in at the inlet hole and extracted through the ventilation pipe.

A pit privy is cheap to build with respect to materials and there should be little odour or fly nuisance, particularly if the inlet hole is kept covered when not in use.

3.4 **Reed odourless earth closet** (ROEC). Figure 3. This is in effect an offset pit privy with an exceptionally large pit, around 3 m^3 volume below the inlet chute. Most designs have access covers so that the pit could be emptied from outside the superstructure. Like conventional pit latrines little information is available on emptying these pits but because of the large storage capacity something like 20 years use could be expected for a single family.

The major drawback with this design is the inevitable fouling of the curved inlet chute. Recent experiences in Botswana have shown that special care with cleaning this chute is essential to prevent fly nuisance due to this fouling. Venting and other design details are the same as for pit privies.

3.5 **Bored hole privy.** In principle similar to the pit privy, but utilises an augered hole of around 400 mm diameter by from 4 m to 8 m deep. Fouling of the sides of the hole is likely immediately below the opening which increases the fly hazard and odour nuisance. For this reason the squatting plate opening should be centrally located over the bored hole, which itself must be vertical to minimise fouling. The augered hole should only be put down in suitable soils that are not only permeable but firm enough not to collapse; large stones make boring difficult and slow. The capacity of the bored hole is much less than that of the usual pit privy, resulting in a shorter useful life. Due to its depth the hole often penetrates and contaminates the groundwater, with the same risk of pollution as for pit privies. When the hole is full emptying is difficult and therefore new holes are frequently required, at around 1 to 2 year intervals according to capacity and usage. Widely used in the Middle East and South East Asia.

3.6 **Double vault compost privy.** Figure 4. Like the pit privy the double vault privy retains excreta during decomposition. By utilising twin vaults or chambers and filling and emptying each vault in turn, periodic digging of a new pit is not needed, as has traditionally been the practice with pit privies. Liquids, other than urine, should not be put into the vaults unless adequate drainage can be provided. The privy superstructure is located over the vault in use and when that vault is full, up to about 500 mm of the privy floor, the vault is sealed and the superstructure moved over the adjacent vault. Alternatively, a larger structure can be built covering inlets to both vaults, one only in use while the other is sealed off. By adequate sizing of the vaults, at say 1.5 m^3 each vault for a family of up to six persons, the waste matter can decompose safely. In around nine to twelve months a useful and harmless fertiliser can be produced in the sealed chamber. Access should be provided for emptying from outside.

By using watertight vaults or by locating the vaults at or above ground level in areas with a high water table or where subject to seasonal wet conditions, the contents of the vaults are not affected and the risk of polluting the groundwater is obviated.

The provision of an effective vent pipe, as for a pit privy, will encourage a downward flow of air through the privy inlet hole and up the vent pipe, reducing odour and fly nuisance and helping to evaporate off excess moisture.

Little information is available of field experiences with this type of latrine and experimentation may be necessary to achieve best conditions for efficient decomposition eg minimum amount of vegetable material needed. In some communities user emptying may not be acceptable by householders;emptying must be a prime consideration when deciding to install compost privies.

3.7 **Compost or biological toilet.** Figure 5. These are forms of composting originating in Scandinavia, where they were originally called 'Multrum' toilets, and are generally expensive and sophisticated installations. In the basic types, without special heating facilities, the temperature achieved during the retention period is not sufficient to destroy the harmful organisms likely to be present in the material being composted. Vegetable material as well as excreta are necessary for effective composting or more accurately 'mouldering' in temperate climates, and to ensure a safe product a long period of retention of from two to four years is advised, to reduce the number of harmful organisms before applying the compost to the land. Kitchen and human waste can be disposed of in this way, by a process not requiring a water supply. The system will be free from odour if a proper vent pipe is incorporated. It is a hygenic system as there is no contact with the decaying material during the process by humans, animals or insects.

Climatic conditions can be much more favourable to the composting process in tropical countries where high ambient temperatures are conducive to rapid biological action within a composting chamber. High enough temperatures could be achieved during composting to destroy organisms harmful to humans. Research is in progress to see how effective this process can be in low-cost installations; recent reports suggest that much care is needed in operating and maintaining these installations to achieve hygenic conditions and effective decomposition.

3.8 **Septic tank.** Figure 6. The septic tank is part of a basic waterborne disposal system and is suitable for individual families or, on a larger scale, for whole communities in rural areas. The process can accept all domestic wastewater. It is a lot more expensive to construct than a simple pit or bored hole, but it is permanent installation, providing a high standard of hygiene and comfort. It requires little maintenance, other than sludge emptying at regular intervals.

A septic tank is effectively a sewage settlement tank, in which the solids are retained in a quiescent state long enough to be partly broken down by anaerobic bacterial action. The tank should be watertight and constructed of non-corrodible material. Raw sewage enters the tank at one end, bacteria digest and liquify some of the settled organic material and the resulting liquid effluent passes out of the other end to secondary treatment and/or disposal eg soakage trench or seepage pit (Figure 9). A suitable vent is required to allow the gases of decomposition to escape from the tank.

During retention insoluble particles accumulate as sludge on the bottom of the tank and a thick scum forms on the surface of the intermediate liquid layer, effectively excluding oxygen and creating the necessary anaerobic conditions. The effluent which flows out of the tank is drawn from the liquid layer and one of the criteria for an efficient septic tank is its ability to retain sewage solids, so that the effluent is relatively free of solid particles. Frequency of desludging can be of the order of from one to five years, depending on efficiency of digestion and sludge storage capacity in the tank.

3.9 **Aqua privy.** Figure 7. This system is based on septic tank principles but is designed to accept only human waste plus some cleansing water. The system requires only sufficient water to clean the bowl or squatting plate and maintain the liquid level in the tank because of losses through evaporation; kitchen wastewater can be used for this purpose. Having less influent the tank requires less capacity than a septic tank in a waterborne system, thus saving on construction costs. There is a correspondingly reduced effluent flow, but with less dilution.

The system uses a straight drop pipe into the tank for the excreta, the pipe discharging through the scum layer and beneath the surface of the liquid. To keep odour and fly nuisance to a minimum the bore of the drop pipe should be no larger than 150 mm; a 100 mm pipe is recommended by some sources for these reasons, plus the fact that scum does not form in a smaller pipe in regular use. A

150 mm pipe is less likely to block however, if larger items of refuse or personal cleansing materials are put into it.

Because of the small size of the aqua privy tank, there is a possibility of some of the influent getting to the outlet pipe before adequate settlement in the tank. This can be prevented by dividing the tank into connected compartments or by providing a baffle between inlet and outlet. A satisfactory secondary treatment can be provided by sub-surface irrigation.

3.10 **Sewered self-topping aqua privy.** A medium to high cost system in which a conventional aqua privy has a pipe system to conduct settled effluent to a separate treatment system, such as waste stabilisation ponds. The tank is self-topping because kitchen wastewater is routed into it preferably via the excreta inlet, thereby also serving as flushwater to clean the appliance. Advantages (7) are low water use as compared with full sewerage and, because of settlement and part-digestion of the sewage in the tank, small bore pipes down to 100 mm can be laid to shallow falls to convey the liquid effluent, which has only finely suspended solids, to the treatment ponds.

3.11 **Pour-flush latrines.** In South-east Asia the pour-flush latrine is a complete system, comprising a shallow water seal pan integral with a squatting plate and discharging to a seepage pit. The pipe from pan to pit should be as short as possible, to reduce the risk of blockage due to the low volume of flush water. Because of the discharge of unsettled solids to the seepage pit, its life will be limited ;solids and biological slime will tend to block the interstices of the soil, eventually preventing drainage of liquids; therefore the seepage pit should be made as large as possible.

The term 'pour-flush' really refers to the type of water seal employed, Figure 8. This device can be used in a variety of sanitation systems, catering for users who normally use water for oral cleansing. Similar to water seals used in developed countries except it has a seal of around 25 mm, necessary because of a much smaller flush volume of around 2 litres. Excreta are discharged through the seal to the disposal system and odours are prevented by the water seal from travelling back; the seal also prevents contact with excreta by flies.

4 POLLUTION OF SOIL AND GROUNDWATER

Great care is necessary in siting excreta disposal installations to avoid pollution of the ground and water supplies by organisms and chemicals that are harmful to health. Human excreta can be a source of infection from pathogenic bacteria and eggs of parasitic worms which are spread through the deposition of excreta from infected persons, passing on infection via the soil and groundwater.

4.1 Spread of contamination

Only the soil surrounding faeces on the surface of the ground is likely to be contaminated, unless infection is carried further by surface water, or is picked up by flies or other insects and animals. It has been observed that hookworm larvae can be present around the opening to pit latrines with floor coverings that are difficult to clean where they can infect humans through contact with the skin, usually bare feet. Pathogenic bacteria do not usually find the soil a suitable environment for multiplication and will die within a few days. However, hookwork eggs are known to survive up to five months in wet, sandy soil (3).

4.2 Contamination of groundwater

A pit privy in dry soil, Figure 10, ie above the water table, has little spread of contaminants, either bacterial or chemical, in a lateral direction and penetration vertically is not likely to exceed 3 metres. If the pit or disposal system has penetrated the groundwater, Figure 11, then bacteria and/or chemical contamination may travel downwards

Table 1 Sanitation systems compared

Sanitation systems compared									
Sanitation system	General suitability		Cost		Technology/skills		Water needs	Health hazards	Nuisance risk: odour, flies
	Rural	Urban	Initial	Ongoing	Construct	Maintain			
Nightsoil bucket and collection	Yes	Yes	Low	High	Very low	Low	None	High	High
Pit privy	Yes	No	Low	Low	Low	Low	None	Medium	Medium
Double vault compost privy	Yes	No	Medium	Low	Medium	Low	None	Medium	Medium
Vault and vacuum tanker collection	Yes	Yes	Medium	High	Medium	Medium	None	Medium	Medium
Aqua privy and soakaway	Yes	No	Medium	Low	High	Medium	Medium	Low	Low
Septic tank and soakaway	Yes	No	High	Low	High	Medium	High	Low	Low
Sewered, self-topping aqua privy	Yes	Yes	High	Medium	High	High	Medium	Low	Low
Sewered full flush	No	Yes	Very high	Medium	Very high	High	High	Very low	Very low

and horizontally, transported by the groundwater; the horizontal movement will always be in the direction of flow of the groundwater.

When locating latrines, regard must be paid to sources of water supply to avoid the risk of pollution. There can be no arbitrary rule governing the minimum distance that is necessary between an excreta disposal pit and a source of water supply, since this will depend on the soil filtering effects and groundwater depth and flow, as well as the amount of pollutant. However it is important to locate a source of pollution, such as a pit privy, downstream from a well or water source, to prevent contaminated groundwater from flowing into the well.

According to Macdonald (8), bacteria rarely travel more than 3 metres downstream through soil, although chemical substances can travel up to 30 metres from point of entry to the groundwater. However, where fissured rock occurs in the sub-soil, as is common in limestone districts, contaminated water can travel considerable distances before being adequately filtered.

4.3 Safe water supplies

Effluent from a septic tank or aqua privy can be as dangerous to health as raw sewage and therefore precautions to protect water supplies from contamination are also necessary for secondary treatment systems, such as soakage trenches and seepage pits. Macdonald (8) recommends the following rules governing location of pollution sources such as pit privies, seepage systems, etc, relative to sources of water supply:

(i) In areas with limestone or other rock formations which may be fissured, disposal systems should be of the watertight septic tank type, either waterborne or aqua privy. They should be located at least 30 metres downhill from a water supply source; when this is not possible the septic tank effluent should be conveyed in close-jointed pipes to a secondary treatment, such as an aeration bed, and then to a final disposal point well clear of springs and wells.

(ii) In areas that are free of fissured formations the disposal system (pit latrine etc) should be located downhill and at least 8 metres from any water supply source. If the latrine etc must be located uphill from the water source it should be at least 30 metres from the source and precautions should be taken to prevent surface water carrying contamination downhill to the water supply.

(iii) On level ground where the direction of flow of the groundwater is not known accurately, or where its direction is liable to variation, the separation of disposal system from water source should be at least 30 metres.

Where direction of flow of the groundwater is known, the recommendations at (ii), for sloping land, apply.

(iv) In all situations the disposal system must be above flood level.

5 CONCLUSIONS

Some alternatives to full waterborne sanitation have been outlined in this paper, with some advantages and disadvantages.

A tremendous amount of experience has been accumulated around the world in the operation of these systems. While research is progressing in many countries to try to develop more effective and economic systems, a lot can be done to improve present technology in order to achieve the fundamental objectives of improved public health and a better living environment.

As part of its work in helping developing countries to carry out their own research and development on building problems, the Overseas Division of the Building Research Establishment can also provide advice and active collaboration in projects aimed at developing better sanitary services.

6 REFERENCES

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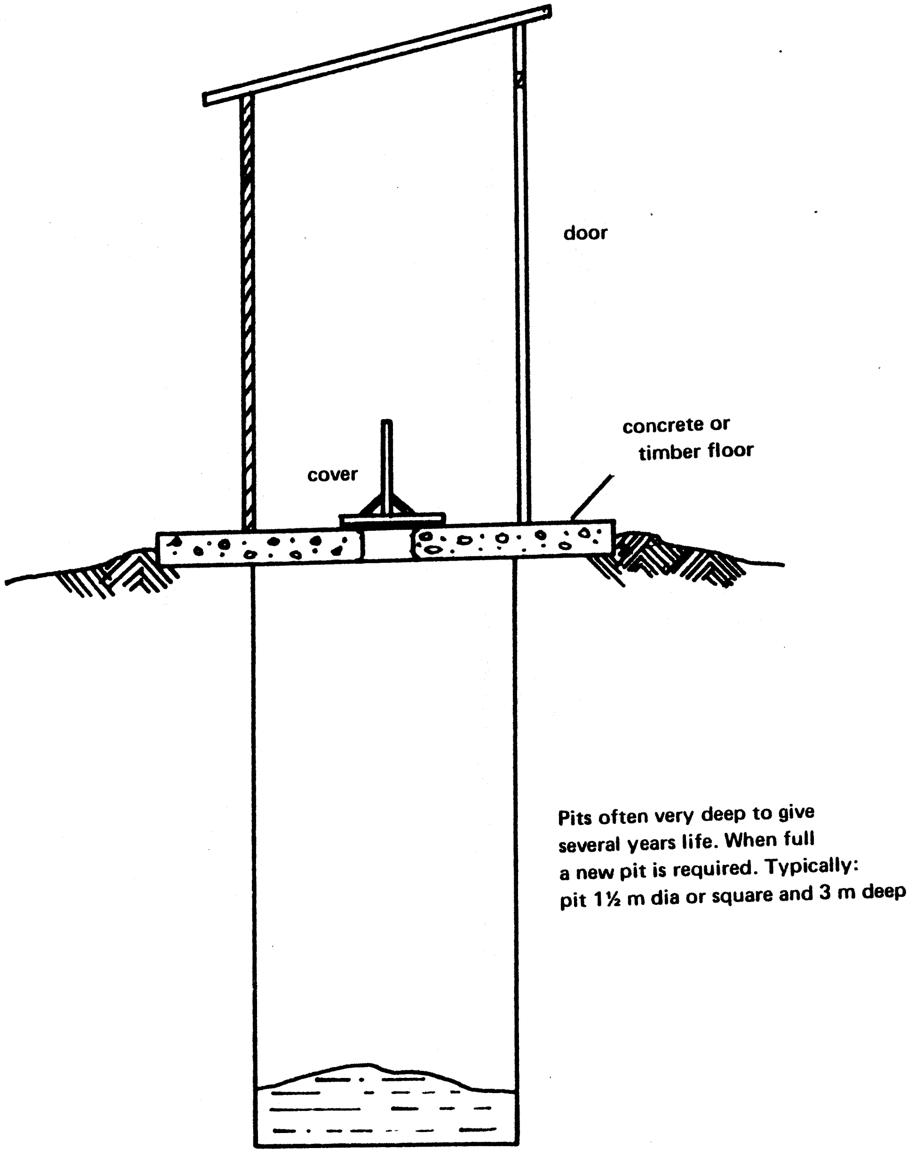


Figure 1 Conventional Pit Privy

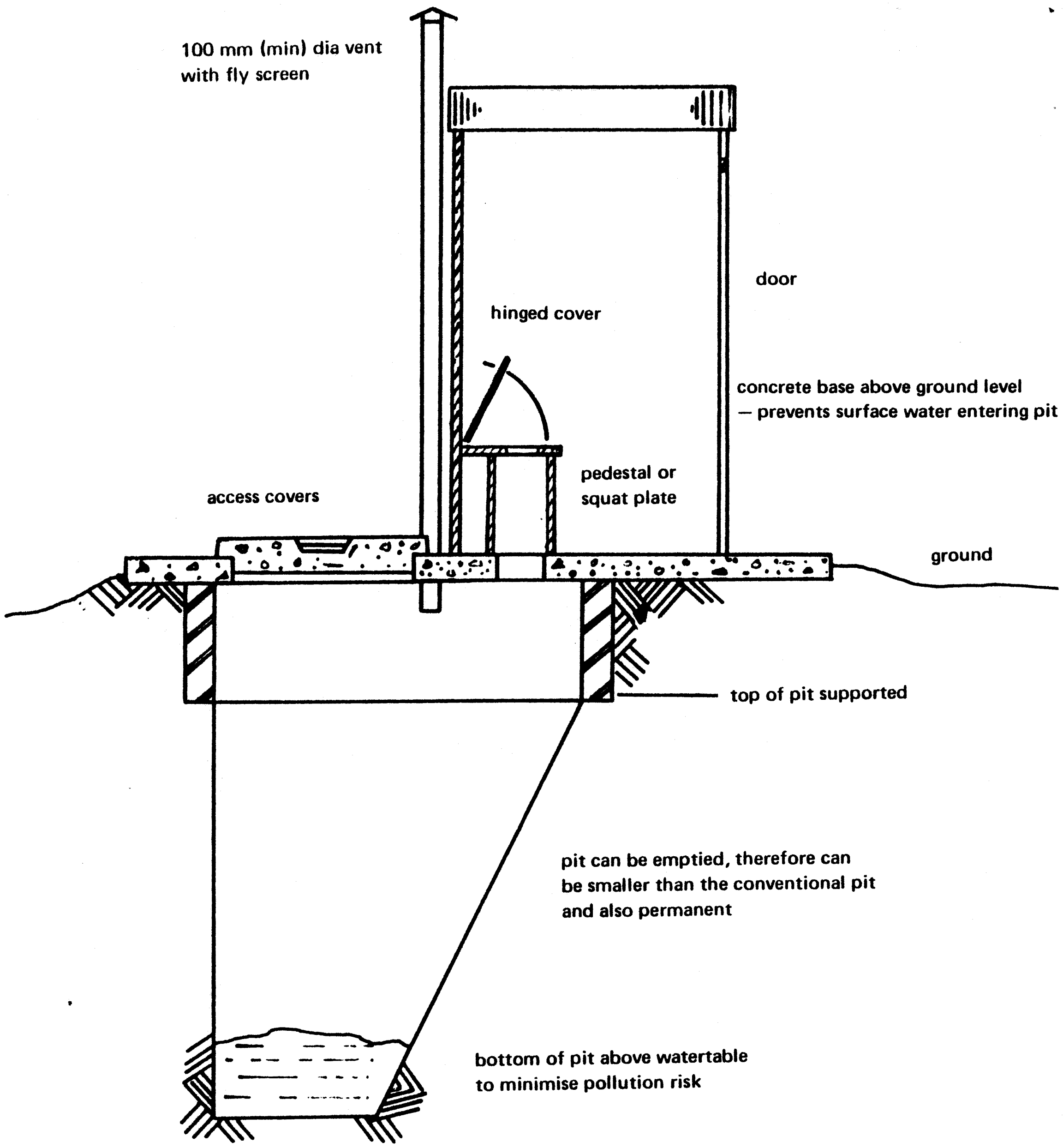


Figure 2 Improved Pit Privy (vented)
(preferably two pits side by side, used and emptied alternately and using a common superstructure)

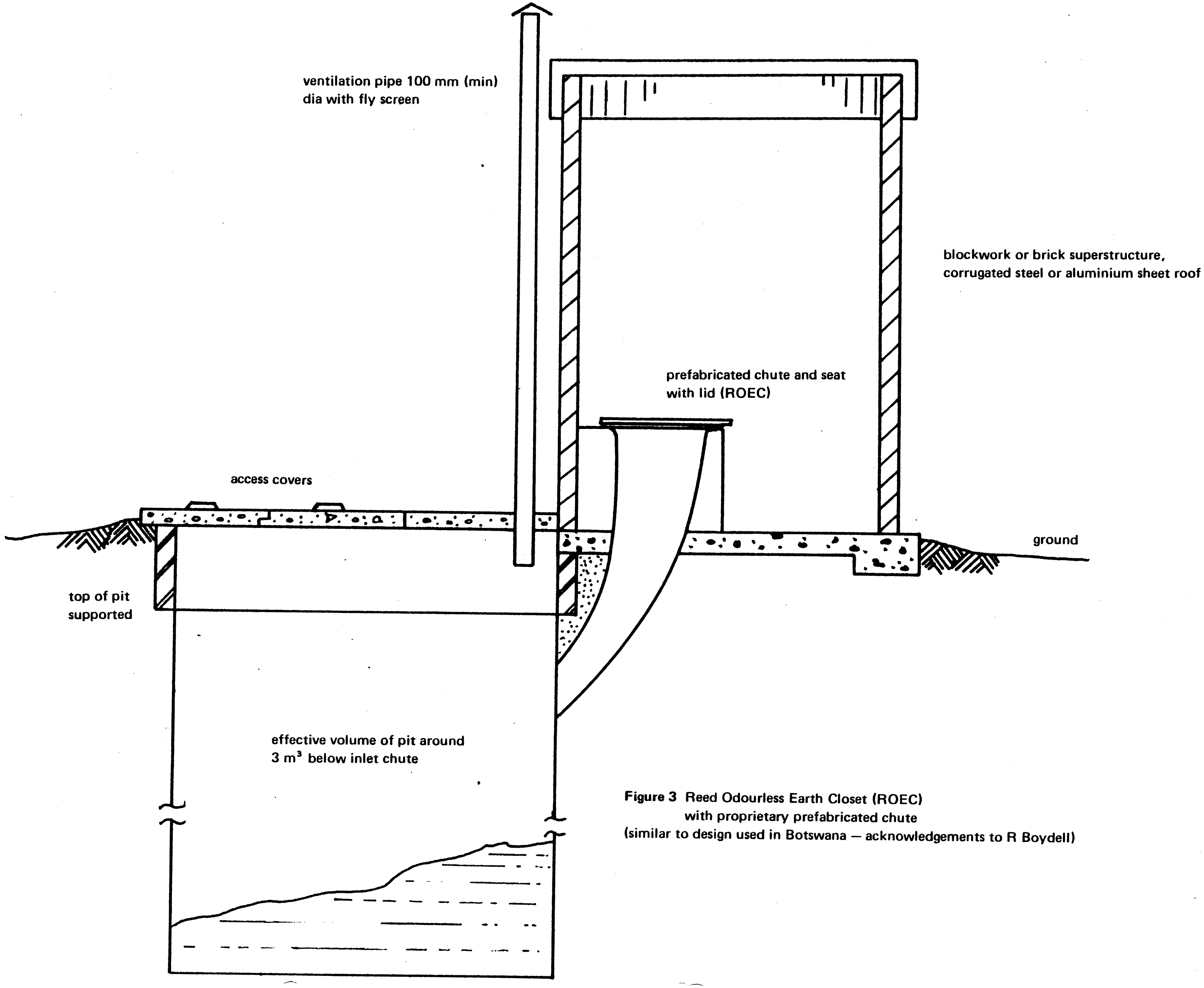


Figure 3 Reed Odourless Earth Closet (ROEC)
with proprietary prefabricated chute
(similar to design used in Botswana — acknowledgements to R Boydell)

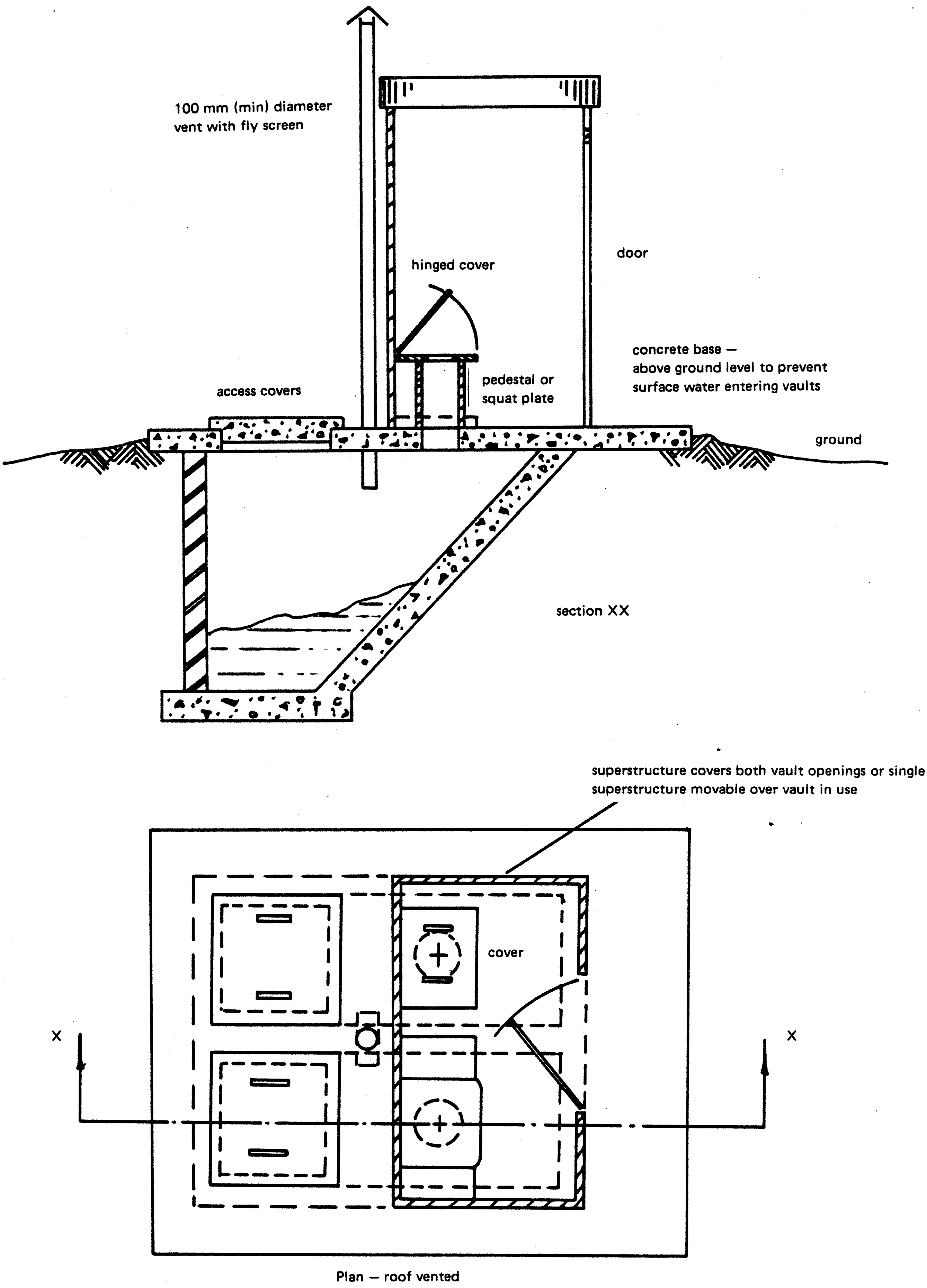


Figure 4 Double-vault Compost Privy (vaults used and emptied alternately)

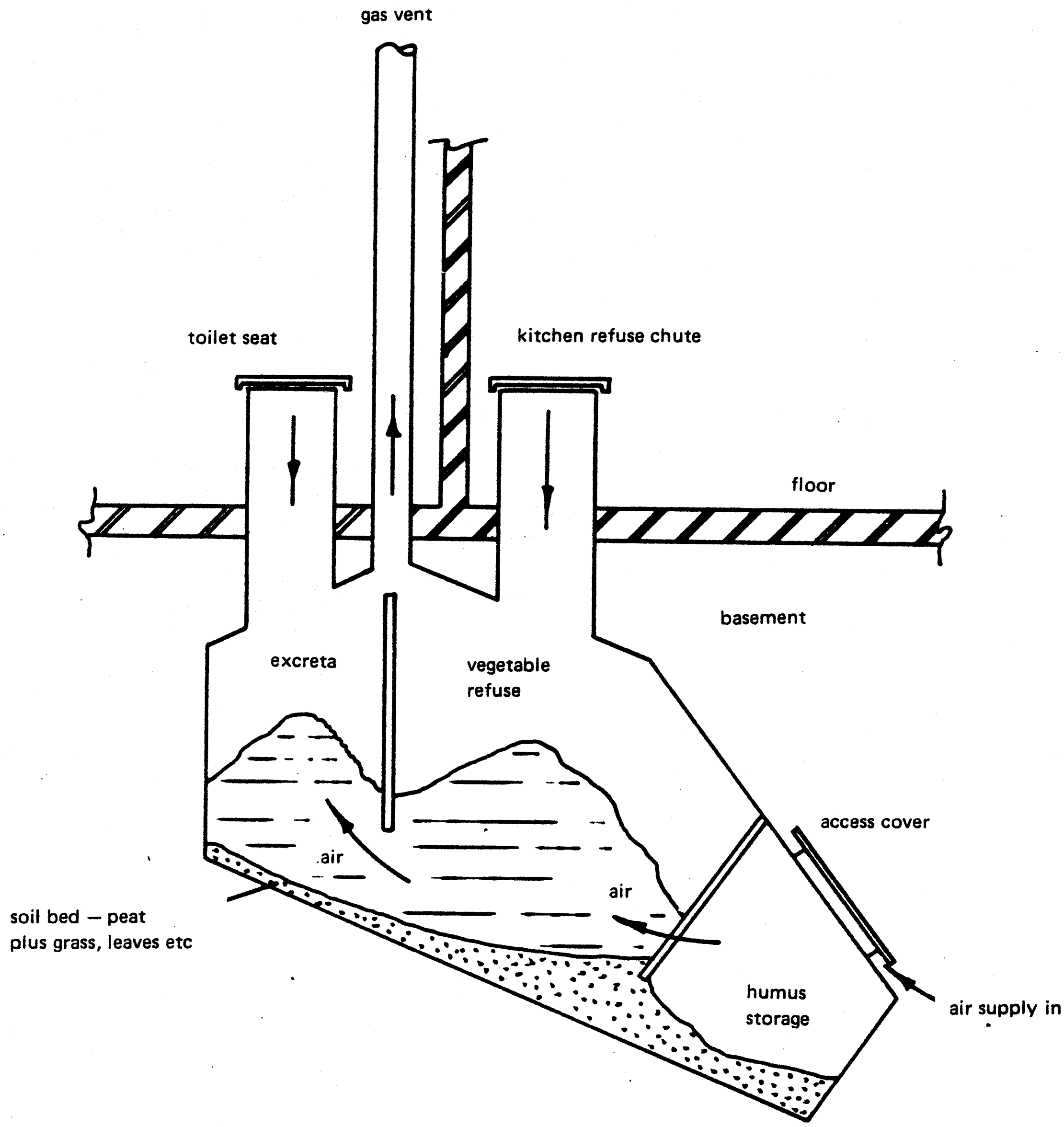
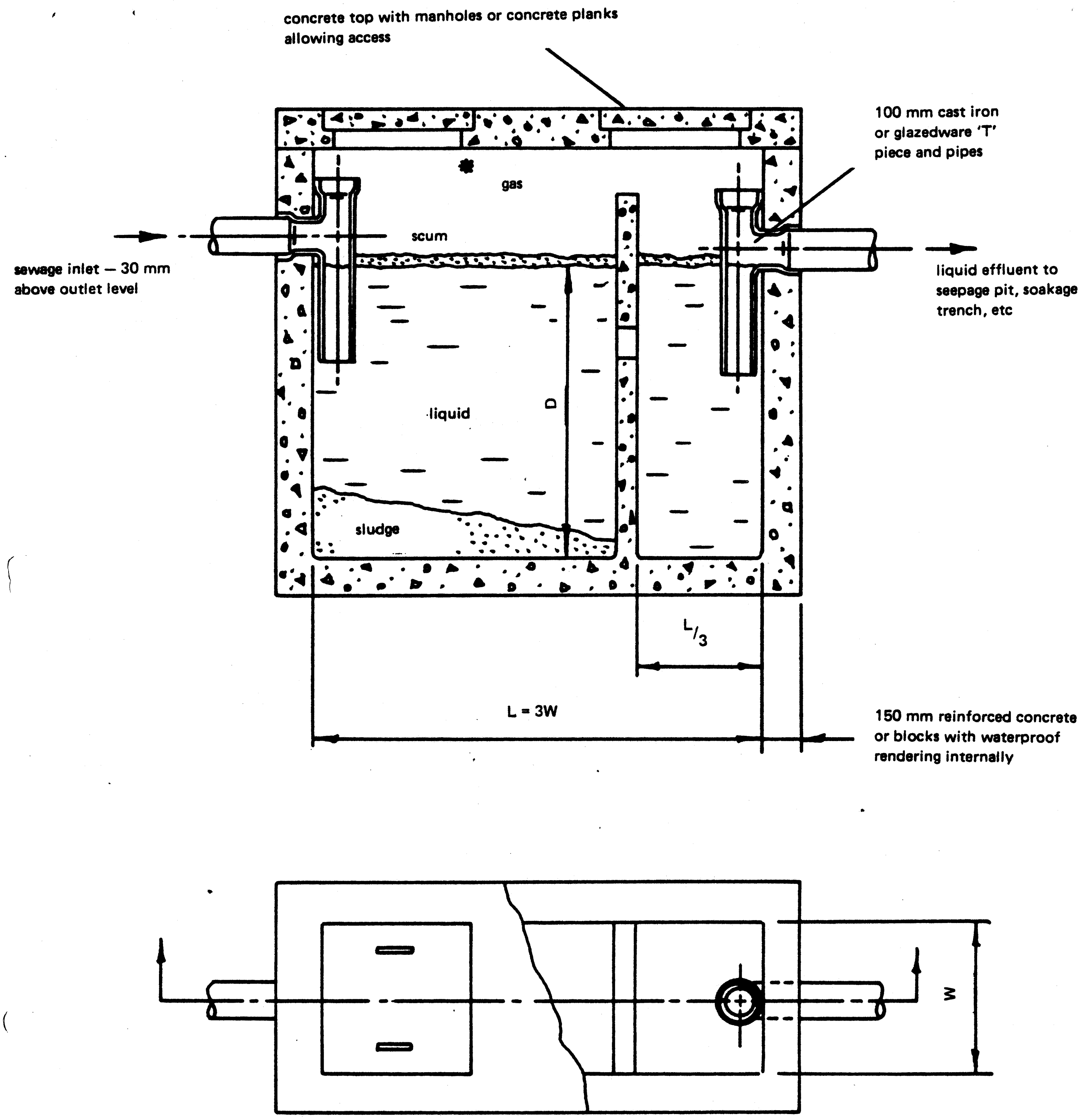


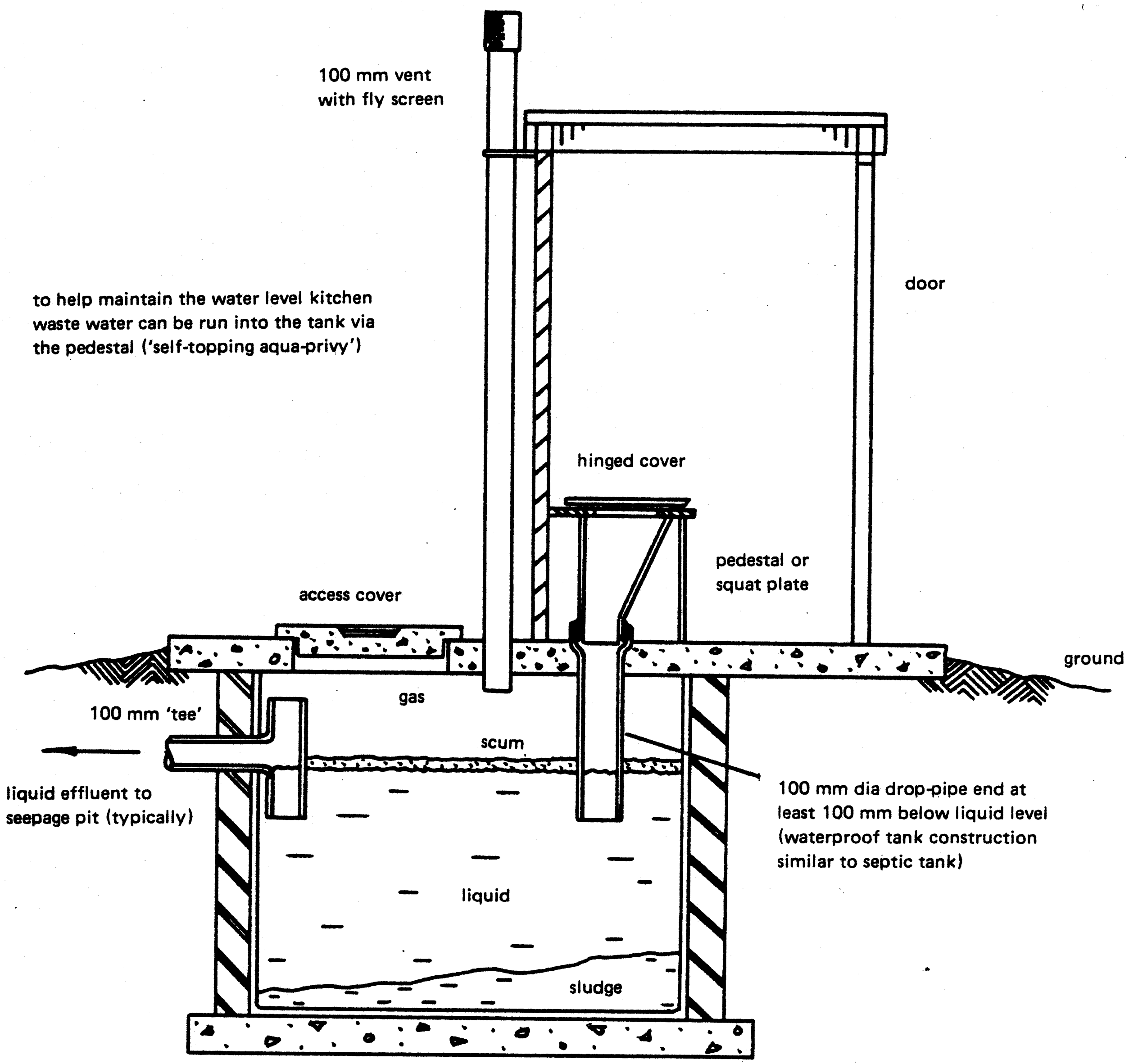
Figure 5 Compost toilet (Multrum)



✱ vent pipe required, either to atmosphere or via inlet pipe to vent near influent source

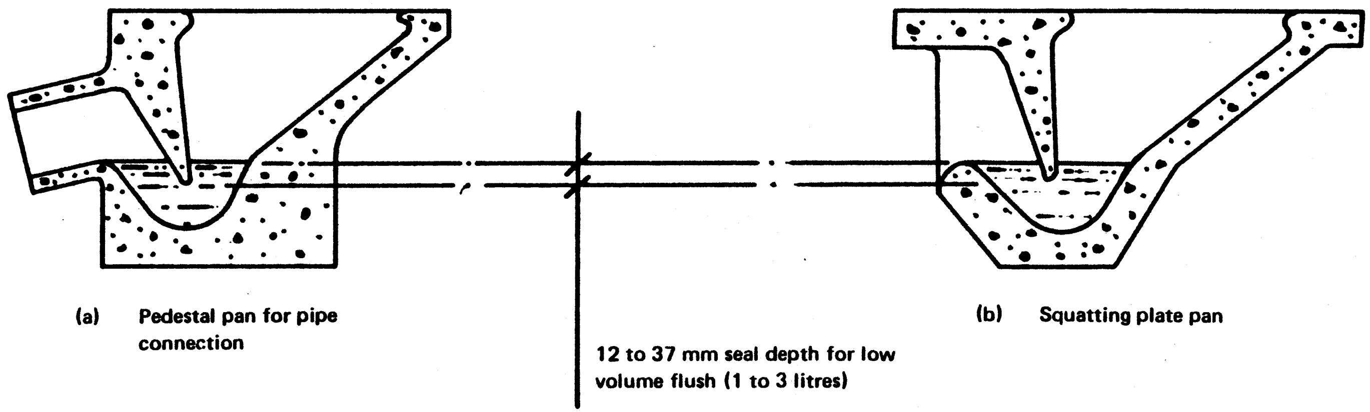
typical tank for 10 persons, waste flow 120 litres/day/person, sludge storage capacity 150 litres/person:
L = 3.0 m, W = 1.0 m and D = 1.1 m (equivalent to 3 300 litres or 3.3 m^3 effective volume)

Figure 6 'Septic tank'



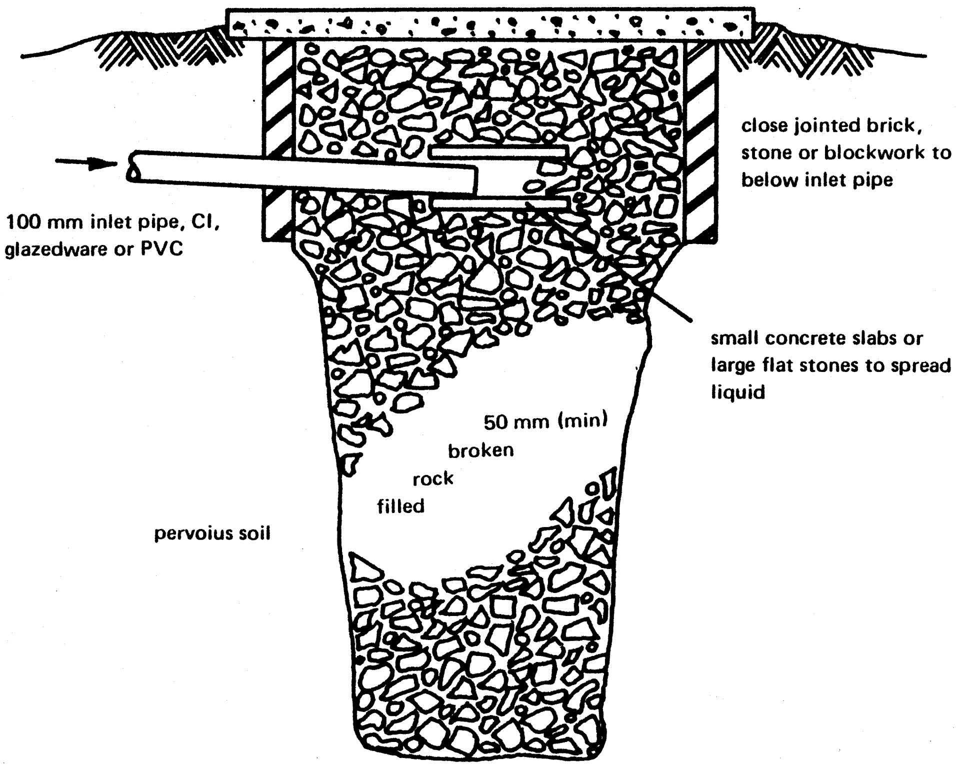
typical tank for 6 persons, waste flow 10 litres/day/person: 1.5 m long, 0.7 m wide and 1.0 m deep (liquid level)

Figure 7 'Aqua-privy'

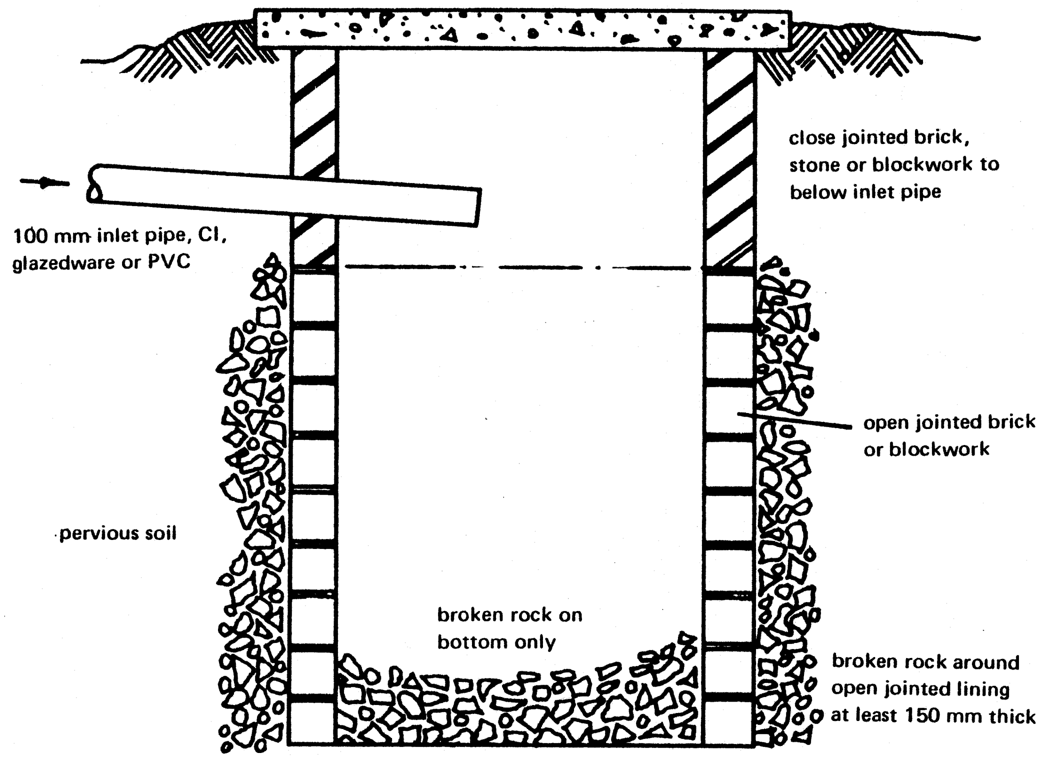


Can be precast concrete with neat cement internal surfaces, to give smooth finish for easier cleaning (see Ref 7 for production details of similar devices)

Figure 8 'Pour-flush' water seal pan



(a) Rock filled pit — top supported, close jointed.
Seepage via fill to soil.
Rock fill supports sides of pit



(b) Unfilled pit — top supported, close jointed.
Remainder open jointed to allow seepage, but providing support to the pit sides.

Figure 9 'Seepage pits' (soakaways)
(in pervious soil only and above the water table)

Note: Pit volume should be at least that of the installation served. Pits are commonly 1.0 to 2.5 m in diameter and 2.0 to 5.0 m in depth (Ref 7) and can be in series

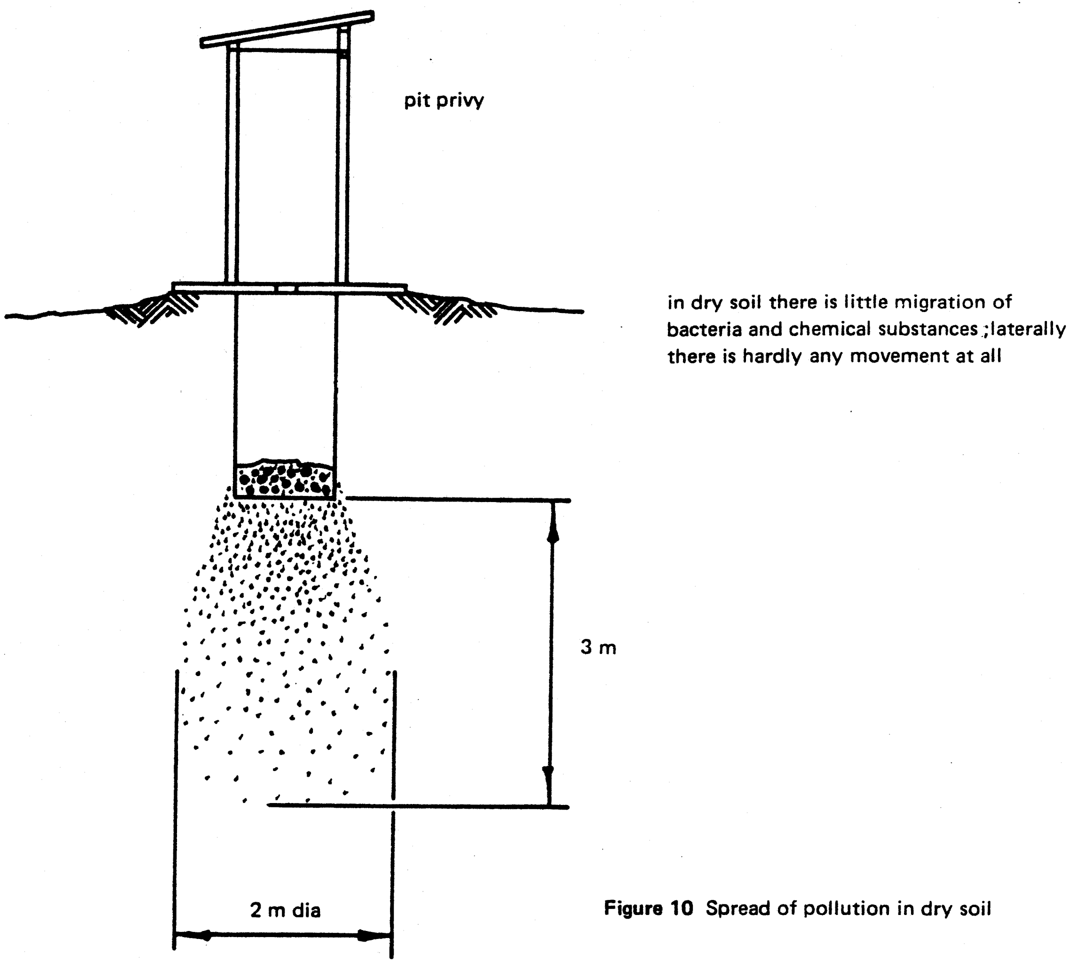
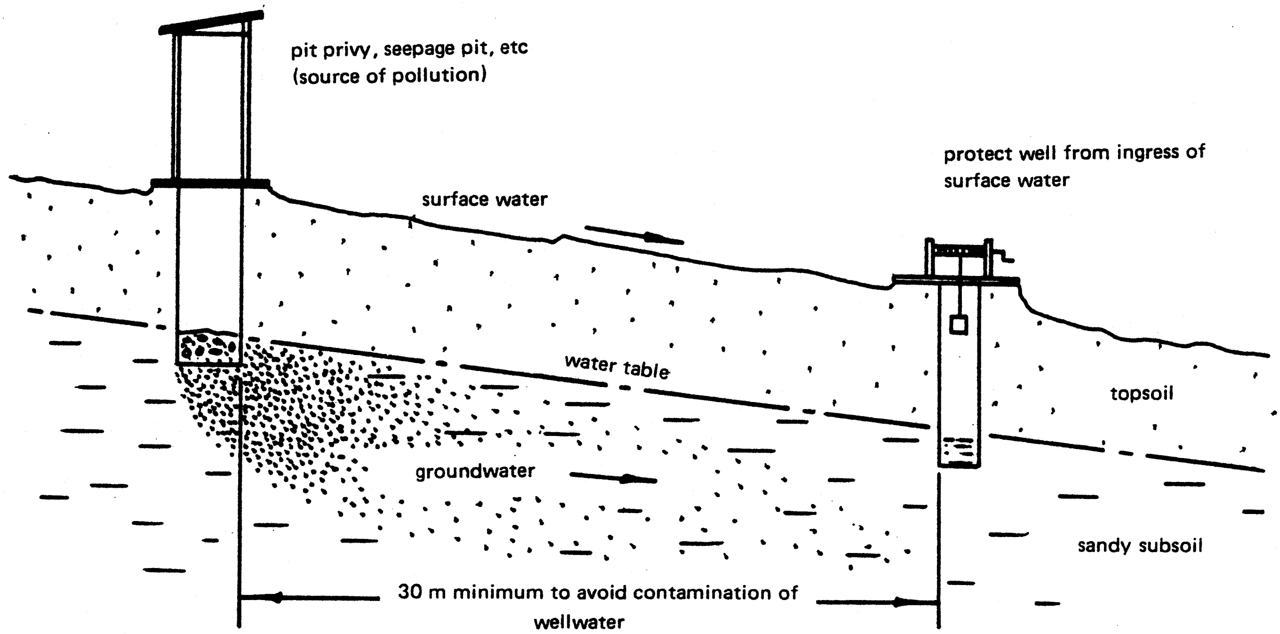


Figure 10 Spread of pollution in dry soil



General rule: pit privies always sited downhill from a water source. If privy must be located uphill it should be at least 30 m from a well.

Figure 11 Siting of privies relative to water supplies