ROSS
BULLETIN
8
January 1978

Small Excreta Disposal Systems

Richard Feachem
Sandy Cairncross

ROSS
The Ross Institute Information and Advisory Service

Plate 1. A ventilated pit latrine in rural Zimbabwe. Improved pit latrines of this type provide a low-cost, hygienic, odour free and acceptable excreta disposal system which is appropriate in many rural settings. (Photo: V. de V. Clarke).

THE ROSS INSTITUTE

Information and Advisory Service

Bulletin No. 8 January 1978

SMALL EXCRETA DISPOSAL SYSTEMS

by

RICHARD FEACHEM

and

SANDY CAIRNCROSS

The Ross Institute of Tropical Hygiene
London School of Hygiene and Tropical Medicine
Keppel Street, Gower Street
London WC1E 7HT

FOREWORD

For over fifty years the Ross Institute has been concerned with the health of those in developing countries. For most of that time its particular responsibility has been with environmental health of those in plantation industries. An essential but unglamorous aspect has been with the sanitary disposal of human excreta, and Dr. O. J. S. Macdonald, the author of the first version of this Bulletin 25 years ago, was a pioneer in improved methods of on-site excreta disposal in South-East Asia.

There followed a period when interest diminished in environmental health, but now health workers are again realising that water and sanitation are not only central to improved health but also provide many challenges and opportunities for imaginative action. The immense cost of conventional sewerage has focused attention back on alternative methods.

Over the years the readership of this Bulletin has widened beyond the planters and mine managers for whom it was originally planned, to include health inspectors, doctors, engineers and teachers. Drs. Feachem and Cairncross, from their extensive tropical experience, have therefore completely re-written this Bulletin to provide a compact and readable account of small excreta disposal systems which will provide a practical guide for those who have to cope with sanitary problems in developing countries. There is a great need for such an account and the authors have filled it most lucidly and usefully.

D. J. Bradley
Professor of Tropical Hygiene
Director of the Ross Institute

PREFACE

In writing a booklet of this kind, it is extremely difficult to decide how much material to include and inevitably the choice will not please all our readers. We have pictured our reader as a person having at least secondary school education but not necessarily having any technical training. This booklet makes clear the range of technologies available for excreta disposal in small communities and describes each system in simple terms. Design formulae are included where appropriate and it is possible using this booklet to design the main elements of the systems described.

In most circumstances, it will not be possible for someone without previous experience actually to construct a latrine using only this booklet. A pit latrine should be possible but other systems will require either previous experience or the assistance of a competent builder. We recommend that, prior to any construction, a detailed look should be taken at systems already in use locally to determine their technical performance and their acceptability to the users. Advice should also be sought from someone with previous experience in latrine construction in the area.

We have tried to emphasise techniques which have been widely used and tested. If, however, you come across unforeseen difficulties, we would be glad to hear from you. We may be able to suggest a solution to your problems and also to make corrections to future editions of this Bulletin.

Other publications on this subject will prove most useful and we have included a reference list at the end of the Bulletin.

ACKNOWLEDGEMENTS

The manuscript of this Bulletin was kindly reviewed by the following specialists in the field. We gratefully acknowledge their helpful comments, which enabled us to improve it considerably. Any errors still remaining are our own.

B. M. U. Bennell, Ministry of Overseas Development.
R. F. Carroll, Building Research Station.
J. N. Lanoix, World Health Organization.
H. Mann, Water Research Centre.
D. D. Mara, University of Dundee.
D. G. Miller, Water Research Centre.
A. Pacey, Oxfam.
M. B. Pescod, University of Newcastle-upon-Tyne.
J. Pickford, Loughborough University of Technology.

In writing this Bulletin the authors have also received much guidance from the staff of the Ross Institute. In particular, Professor D. J. Bradley and Dr. D. M. Mackay reviewed the manuscript and made detailed comments. The authors are also indebted to Mrs. Agnès Candler for her invaluable assistance.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE ACKNOWLEDGEMENTS

Some figures in this Bulletin have been reproduced or adapted from figures published elsewhere. Copyright permission is gratefully acknowledged for those figures below. Requests for permission to reproduce them should be addressed to the respective publishers. Where changes have been made, the responsibility for errors is our own.

Figure	*Source*
2, 6, 8, 20, 23, 32	Wagner, E. G. and Lanoix, J. L. (1958) *Excreta Disposal for Rural Areas and Small Communities*. Geneva: World Health Organization.
7, 28	Cotteral, J. A. and Norris, D. P. (1969) Septic tank systems. *J.S.E.D., Amer. Soc. Civil Engrs.*, **95**, 715-746.
9	Pradt. L.A. (1971) *Water Research*, **5**, 8, 507-521.
11	Shelat, R. N. and Mansuri, M. G. (1977) In Feachem *et al.*, eds.: *Water, Wastes and Health in Hot Climates*. London: © John Wiley & Sons. Designs by Dept. of Social Welfare, Ahmedabad.
12	Mara, D. D. (1977) In Feachem *et al.*, eds.: *Water, Wastes and Health in Hot Climates*. London: © John Wiley & Sons.
13	Solly, R. K. (1977) *Appropriate Technology*, **3**, 4, 23-25.
16, 17, 22	Unpublished drawings by R. A. Boydell, Ministry of Local Government and Lands, Gaborone, Botswana.
21	Oluwande, P. A. (1976) *Appropriate Technology*, **3**, 3, 26-28.
24	U. K. Ministry of Defence (1976) *Manual of Army Health*. London: H.M.S.O. British Crown Copyright; reproduced by permission of the Controller of Her Britannic Majesty's Stationery Office.
26	Rajagopalan, S. and Shiffman, M. A. (1974) *Guide to Simple Sanitary Measures for the Control of Enteric Diseases*. Geneva: World Health Organization.
29	Bouma, J. et al. (1975) *Journal of Environmental Quality*, **4**, 3, 382-388. Reproduced by permission of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.
30	Malan, W. M. (1964) CSIR Research Report No. 219. Reproduced by permission of the Director, National Institute for Water Research, CSIR, Pretoria, South Africa.
31	Mara, D. D. (1977) Overseas Building Note No. 17. Garston: Building Research Establishment.
Cover	We are grateful to Ms. J. Allen for designing the cover for this Bulletin.
Art work	We are grateful to Pauline Berrington and Jane Symons for preparing many of the drawings in this Bulletin.

Plate 2. A simple pit latrine in rural Kenya. A latrine of this sort may be quite acceptable for many years but tends to become smelly and to attract flies. It may be improved by adding ventilation as shown in Plate 1. (Photo: R. G. Feachem).

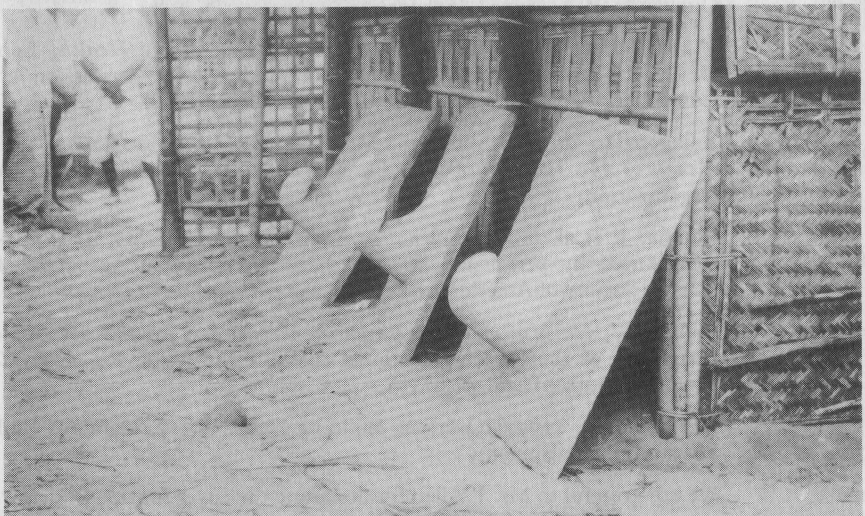


Plate 3. The underside of concrete pour flush bowls and squatting slabs, made for installation onto pit latrines in Bangladesh. (Photo: R. G. Feachem).

CHAPTER 1 MEDICAL AND SOCIAL PERSPECTIVE

1.1 SANITATION AND HEALTH

The hygienic disposal of human excreta is of the utmost importance to the wellbeing of all communities. It is necessary for the preservation of health, and indeed the correct disposal of excreta is one of the most effective measures which any community can undertake to improve its health. The sanitary disposal of human wastes will help to control all those infectious diseases which are caused by pathogens[1] excreted by people in their faeces or urine. Table 1 provides a list of some of the more important infections transmitted in the faeces. The reader will note that some of the world's major infectious diseases are included in this list. Of particular importance are diarrhoeal diseases, cholera, typhoid and schistosomiasis. By comparison with faeces, most diseases are very rarely, if ever, transmitted in urine. But there is a notable exception; schistosomiasis, which is transmitted partly, and sometimes primarily, in the urine of infected persons.

TABLE 1

Some important infectious diseases related to the unhygienic disposal of human faeces

Bacterial Infections
- Typhoid
- Cholera
- Bacillary dysentery
- Miscellaneous diarrhoeas and gastro-enteritis

Viral Infections
- Infectious hepatitis
- Poliomyelitis
- Miscellaneous diarrhoeas

Protozoal Infections
- Amoebic dysentery (amoebiasis)

Helminthic (worm) Infections
- Roundworm (ascariasis)
- Hookworm
- Bilharzia (schistosomiasis)

The sanitary disposal of human wastes is perhaps of greater importance than the provision of a safe water supply because, if the disposal of human excreta is correctly managed, there will be little risk of human faecal contamination of domestic water sources. It is better to protect the environment from faecal pollution than to undertake expensive measures to reduce the pollution when it has already taken place.

1.2 SOCIAL DIMENSIONS

Excreta disposal, then, is important. But it is extremely difficult to achieve changes in excreta disposal practices. They are part of the basic behavioural pattern of a community and are not readily modified. Many Europeans have difficulty in adopting a squatting position for defaecation and are reluctant to use water and hand for anal cleansing when visiting parts of Asia where this is the custom. Similarly, many villagers, used to promiscuous defaecation in the bush around the village, are reluctant to adopt the use of a latrine – especially one that becomes fouled through improper use or insufficient maintenance.

There is absolutely no point in building latrines if they will not be used, and an appreciation of the acceptability of a particular form of sanitation to the community is an essential first step in any programme. It is necessary to understand existing defaecation practices and beliefs. It is necessary to develop any sanitation programme in close cooperation with community leaders. It is essential to provide the training and extension work necessary to acquaint the community fully with the method of using and maintaining the particular type of latrine. It is always necessary to take account of community feelings concerning the sanitation programme.

Excreta disposal in rural areas is far more complex socially than it is technically and it is not appropriate to assign total responsibility for rural sanitation programmes to engineers. A rural sanitation programme requires a team combining engineers, community workers and health personnel. If a dominant role needs to

[1] Technical terms such as this are explained in the glossary at the back of this Bulletin.

be ascribed, it should in general be to the community workers who have the closest contact with the people who will use the facilities provided. In some countries it may be appropriate to assign responsibility for excreta disposal to the village-level health workers or 'bare-foot doctors'.

Whatever type of personnel is involved, it is vital for them to realise that the improvement of sanitation is not completely achieved by the construction of a latrine. Follow-up visits to the home are needed to check whether the latrine is being used, whether it is being kept clean, whether a real improvement in domestic hygiene has been achieved, and whether any maintenance problems are emerging. The person making these visits should preferably be a health worker of some kind, and possibly a woman, so that she can talk freely with the housewife, but she should be able to call on technicians where necessary to maintain and repair the latrine, and to desludge any aqua privies or septic tanks.

All these follow-up activities require a substantial commitment in manpower and funds, but a sanitation programme has little chance of success without them. It is essential to resist the temptation to go on building new latrines beyond the capability to supervise and service them.

CHAPTER 2 THE ELEMENTS OF THE SYSTEM

2.1 INTRODUCTION

There is a range of alternative technologies for excreta collection and disposal in urban and rural areas. Many of them have common features and there is considerable room for flexibility in the selection and combination of different elements of the complete system. It is helpful to break down the overall process of collecting and disposing of human wastes into six stages: *deposition, collection, transportation, treatment, disposal* and *re-use*. Figure 1 shows the elements which can be used for each stage. Each box in Figure 1 is an element, and the arrows show how they can be connected to form a complete sanitation system. Of course, the elements can only be combined in certain ways, and these are shown by the arrows. Some of these combinations are not often used, or are not very practical, and these are shown by broken lines.

In this chapter we describe the elements used for each stage and what they do. Then in Chapter 3 we discuss the particular combinations we recommend for use in small communities, and the factors affecting the choice of the most suitable one. Chapter 4 describes in detail the design and construction of each system, and finally Chapter 5 discusses several issues common to all of them.

2.2 DEPOSITION

Deposition refers to the act of defaecation itself. Three possible technologies are commonly used. The most important differences between them are (a) how the excreta are removed, and (b) how the latrine is sealed off to prevent odours, flies etc. coming up from the place where the excreta are collected.

Squatting slab

A squatting slab is simply a plate with a hole and raised foot-rests and is the simplest form of deposition structure. The excreta are removed by gravity, by falling through the hole. A lid should be provided to cover the hole when not in use. A possible design is shown in Figure 2.

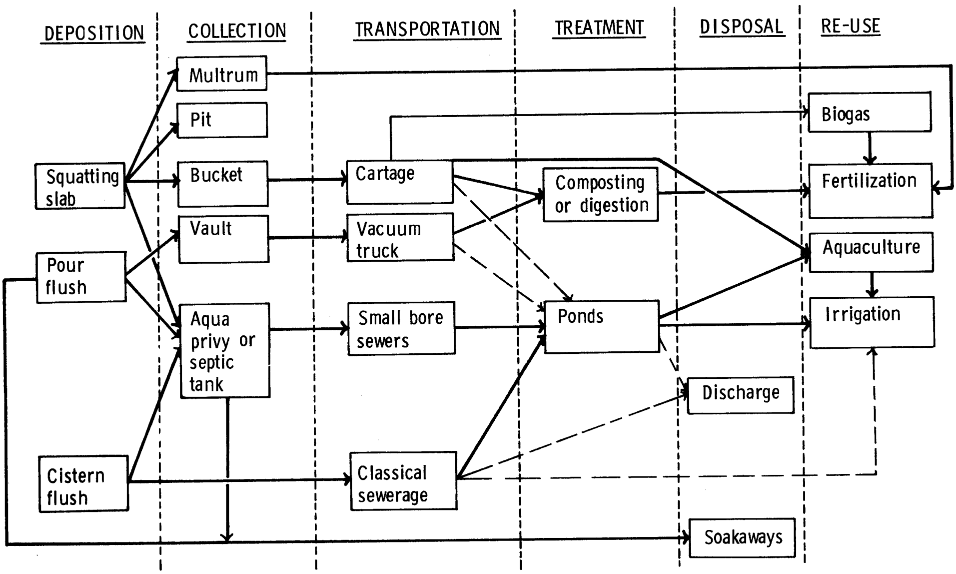
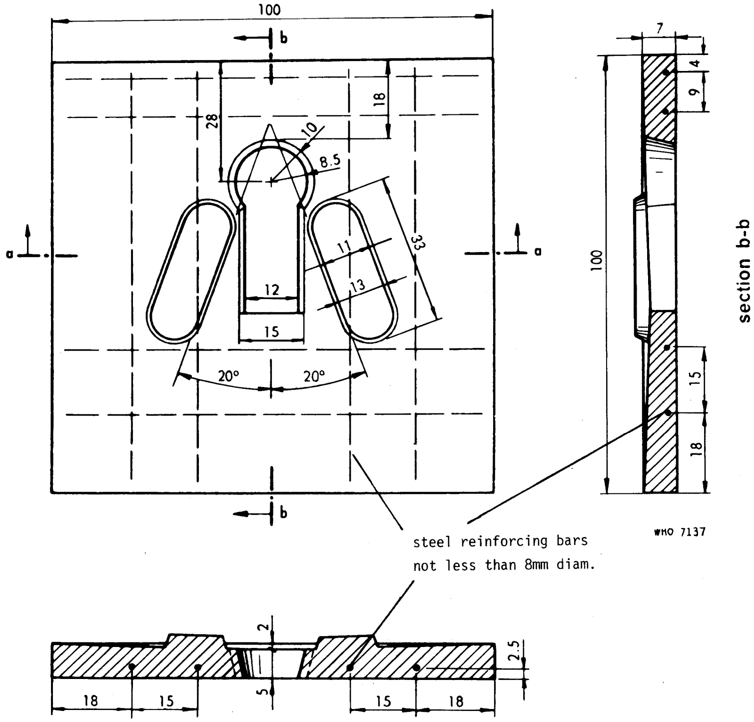
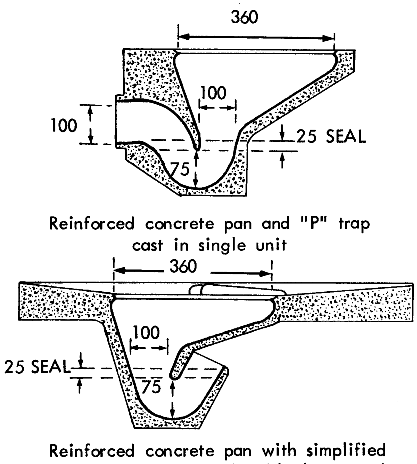


Fig. 1. The elements of an excreta disposal system and the various ways in which they can be combined.



section a-a Measurements shown are in centimetres.

Fig. 2. Square concrete squatting slab for a pit latrine. (From Wagner & Lanoix).



All measurements are in millimetres

Fig. 3. Alternative types of pour-flush latrine pans for use with septic tanks, aqua privies or pour-flush and soakaway systems.

Water seal with pour flush
A water seal is made by a U-pipe filled with water, below either a seat or a squatting pan. If it is carefully designed, with a water seal of only 15-25 mm, it can be flushed by pouring a small volume of water down it by hand; usually 1 to 3 litres. Typical designs are shown in Figure 3. This method is widely found in South East Asia.

Water seal with cistern flush
In this case a flushing volume of 10 litres or more is delivered from a cistern which is connected to the mains water supply. The water seal can be under a squatting pan or a seat. In the latter case it is the system almost universally used among high-income groups in all parts of the world. A cistern flush connected to a squatting pan is shown in Figure 4.

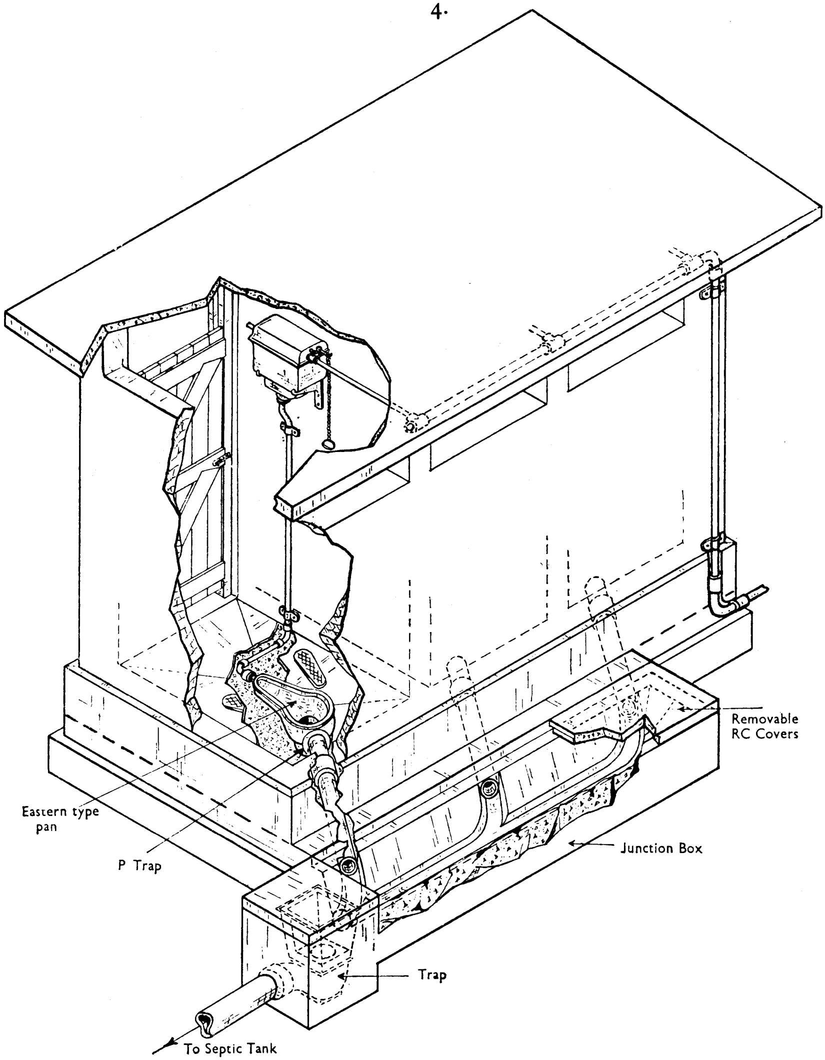


Fig. 4. A communal cistern flush latrine with a hand-operated cistern in each compartment.

2.3 COLLECTION

After deposition, the excreta are normally collected in a pit, tank or bucket.

When excreta are kept in one place for a period of time (the 'retention time'), various bacteria feed on them and cause them to decompose slowly. This process is usually called 'digestion'. In most of the systems described in this Bulletin, it takes place under water. If not under water, it is usually called 'composting'. For composting to work well, some organic waste such as food left-overs and ashes should be added to the excreta. Depending on the amount of air available, different bacteria will multiply and digest excreta; the digestion can be aerobic (with air) or anaerobic (without air). Roughly speaking, aerobic digestion is faster, hotter and more complete, but is less easy to arrange, at least after the initial stages when any oxygen available is quickly used up.

The main alternatives for the collection of excreta are discussed below.

Pits

In a pit latrine, the excreta are collected in a hole in the ground, generally located directly beneath a squatting slab, and usually dug by

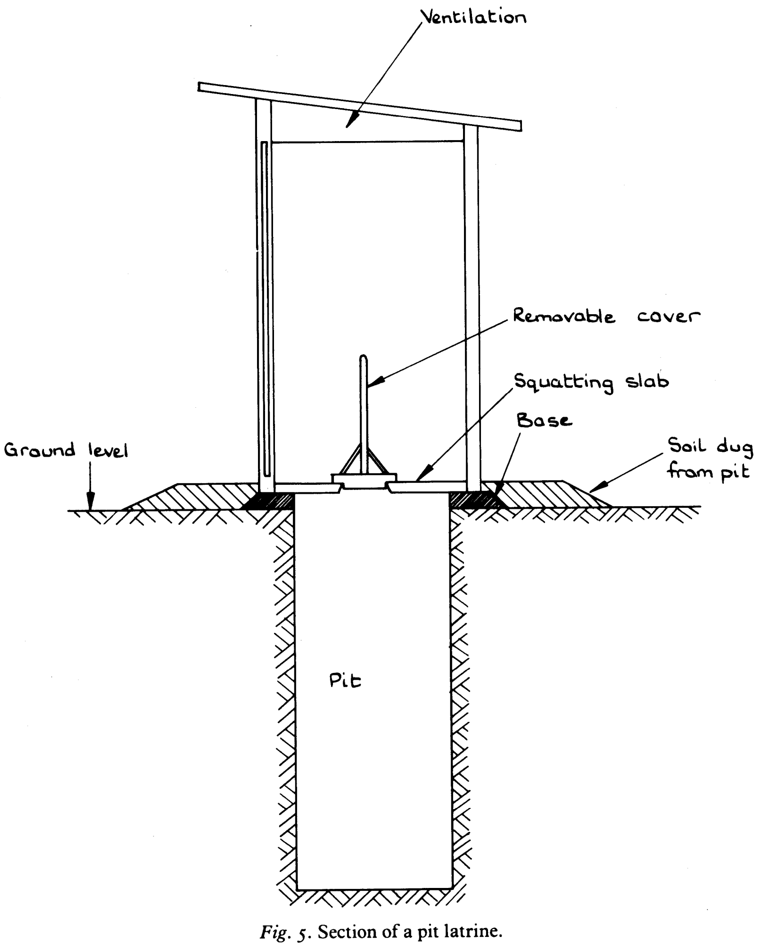
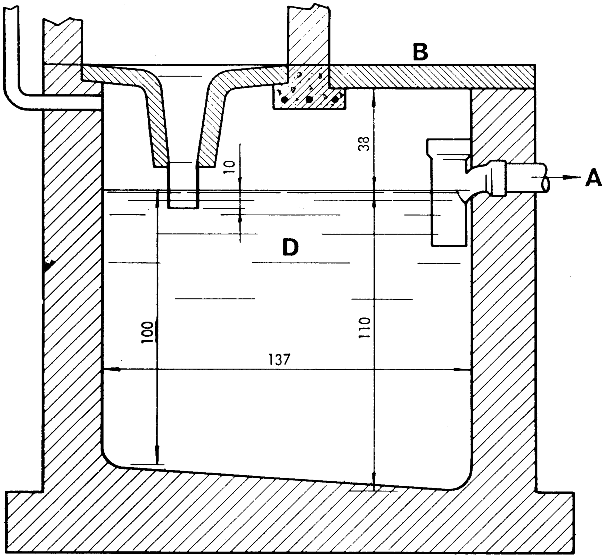


Fig. 5. Section of a pit latrine.

hand. A typical design is shown in Figure 5. When the pit is two-thirds full, it is filled in with earth and a new pit is dug nearby.

Excreta can be composted in a pit. A composting pit latrine uses two pits, side by side. The excreta in one pit are digested while the other is being used, and are then dug out for use as fertilizer.



Section a-a

Measurements shown are in centimetres.

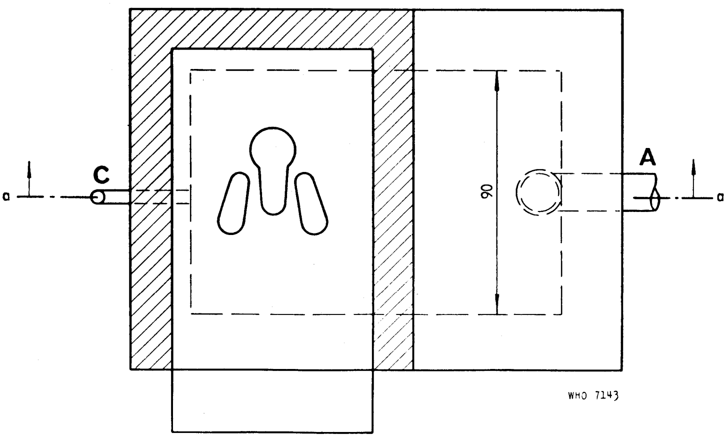


Fig. 6. Basic aqua privy for a single family. (From Wagner & Lanoix).
A = Outlet to soakage trench or soakage pit.
B = Removable, reinforced concrete cover slab.
C = 100 mm diameter pipe ventilator.
D = Capacity of tank: 1340 litres.

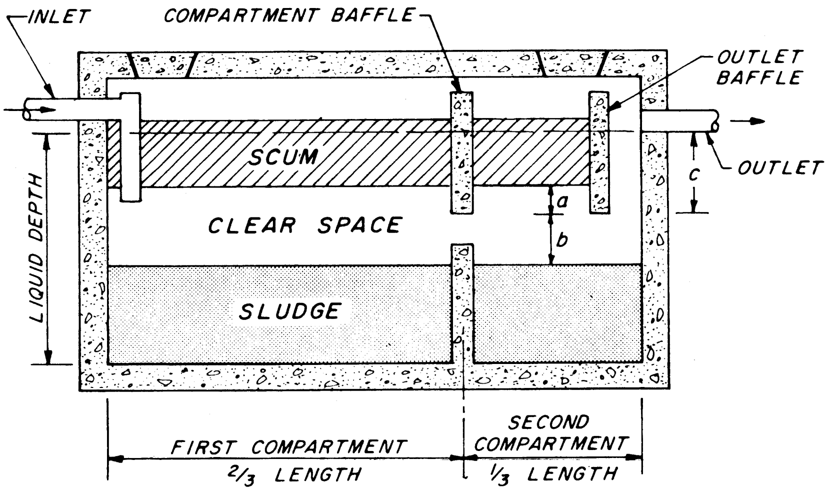


Fig. 7. Two compartment septic tank: a = scum clear space (75 mm. minimum); b = sludge clear space (300 mm. minimum); c = 40% of liquid depth. (From Cotteral & Norris).

Aqua privy
An aqua privy is a water-filled tank located directly underneath the point of defaecation. The user usually squats on a squatting slab and his excreta fall directly down a tube or a chute into the water-filled tank. The tank allows the solid material to settle and form a 'sludge' to be digested anaerobically at the bottom, while the liquid 'effluent' flows out through an outlet pipe. The tank has to be kept full of water, to provide a water seal against odours. The basic arrangement is shown in Figure 6. The effluent from an aqua privy usually flows to a soakaway but it may also be fed into a sewerage system. The sludge which accumulates in the tank must be periodically removed.

Septic tanks
The septic tank is a widely used collection device and is suitable for individual dwellings, or groups of houses, usually in high or medium income areas. It is a water-tight settling tank normally located underground, away from the house or toilet. Wastes are carried to it by water flushing down a sewer. Septic tanks normally take all waste water from the dwellings they serve (Figure 7).

A septic tank does not dispose of wastes; it only helps to separate the solid matter and to digest it anaerobically, in the same way as an aqua privy tank. The liquid effluent flowing out of the tank remains to be disposed of, normally by soakaways (Section 2.6). The sludge must be periodically removed.

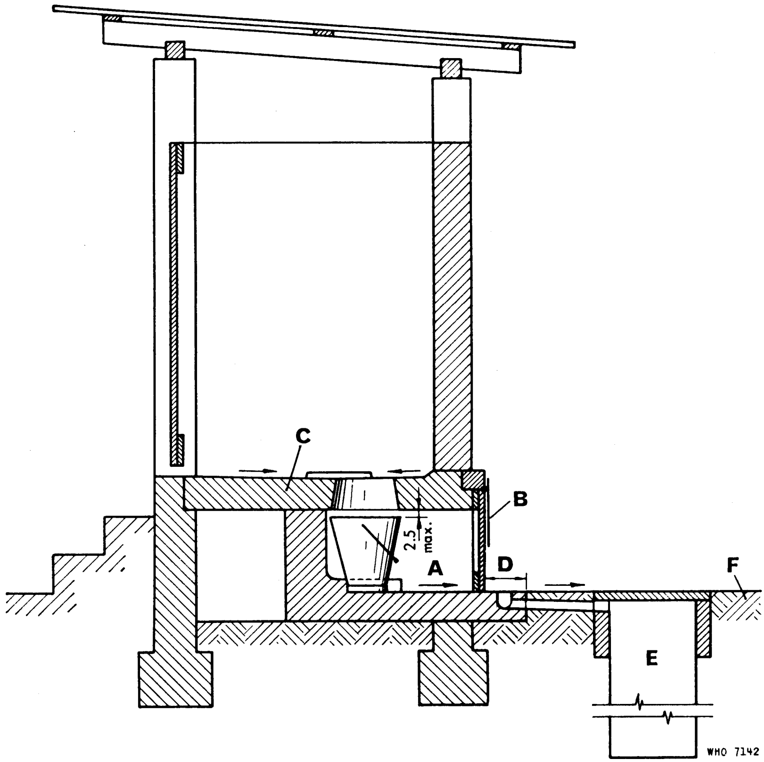
Cesspools
The word 'cesspool' means different things to different people. Basically a cesspool is merely a covered chamber receiving all waste waters from a dwelling or dwellings. If the cesspool is sealed and has an outlet pipe it is indistinguishable in principle from a septic tank. An unlined cesspool may act as a soakaway (see below) until all pores in the surrounding soil become clogged, whereupon it becomes a septic tank. A more common usage of the word cesspool describes a sealed tank with no overflow in which liquid wastes and sludge are stored. Frequent emptying (at least once every six months depending on the size) is required and the system is therefore expensive and reliant upon whichever central authority is operating the collection service. The cesspool could then be considered as an expensive variation of the vault system.

Bucket latrines

One of the oldest and generally least hygienic systems is the bucket latrine. A squatting slab or seat is placed immediately above a bucket which is filled within a few days by the excreta of an average family (Figure 8). The bucket is positioned adjacent to an outside wall and is accessible from the street or lane. A sweeper will call regularly – preferably every day but more typically once or twice a week – and will empty the bucket.

Vaults

Many households in Japan, Taiwan and other countries store their excreta, plus the small amounts of water used for pour flushing and anal cleansing, in sealed vaults under or beside the house (Figure 9). These vaults are emptied about once every two weeks by a vacuum truck. This system has relatively high operating costs but may have relatively low initial costs. It is suitable for high density urban areas where access by truck is possible and truck maintenance facilities exist.



The measurement shown is in centimetres.

A = Collection chamber built of impervious material; note bucket
B = Fly-proof door
C = Elevated floor or slab
D = Paved surface and drain
E = Soakage pit or trench
F = Original ground-level

Fig. 8. A bucket latrine with squatting slab. (From Wagner & Lanoix).

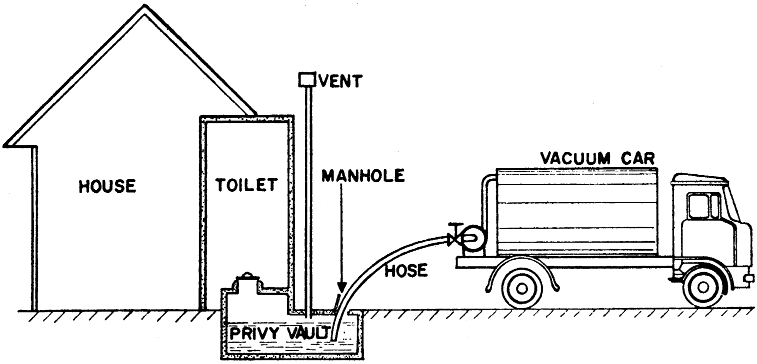


Fig. 9. Typical arrangement for household nightsoil collection, with vault and vacuum truck. (From Pradt).

Multrum

The 'multrum' dry composting toilet is a technology for the continuous composting of a mixture of human wastes and refuse. It was developed in Sweden and has not yet proved its worth in the tropics or among low-income communities. An experimental multrum design is shown in Figure 10. Multrums are currently (January, 1978) undergoing extensive trials in Botswana and Tanzania and they cannot be recommended until these trials are completed.

2.4 TRANSPORTATION

Waste material is either piped in a flow of water through a sewerage system or is carted without added water. These alternatives are discussed below, but it should first be noted that there is no point in having a transportation system unless there is somewhere for the waste to go. That is, a treatment or disposal system of some kind.

Sewerage

A *sewerage* system is a network of large diameter pipes (called *sewers*) laid at fairly steep grades (slopes) along which waste water containing human wastes (called *sewage*) flows. It is the system found in most communities in Europe and North America and in certain high-income communities elsewhere. Sewerage systems are extremely expensive because they involve laying large pipes in deep trenches. Unless the lie of the land is unusually favourable, they also involve pumping stations. The design of sewerage systems is a complex, but relatively routine exercise for a qualified sanitary engineer and is described in many standard texts on the subject (e.g. Okun and Ponghis, 1975). Large quantities of water are needed to move solid wastes along a sewer pipe, so that a cistern flush is normally necessary. The amount of water used in a pour flush system is only enough to flush excreta a few metres along a straight pipe.

A cheaper form of sewerage is possible where only liquid wastes are to be transported, as in the case of the effluent from an aqua privy or septic tank. Because there are no large solids, smaller diameter pipes may be laid at flatter grades and so considerable cost savings may be achieved.

Cartage

A cartage system is one in which human wastes are transported by human or mechanical means, without the use of water for flushing. Human faeces and urine transported in this manner are often called *nightsoil* and are sometimes re-used for agriculture or in fish ponds.

At its simplest, a cartage system is a man with buckets, often carried on a yoke, which he fills from bucket latrines. The next stage up is a hand-pushed cart (Figure 11) or a donkey-drawn cart. Beyond this, various

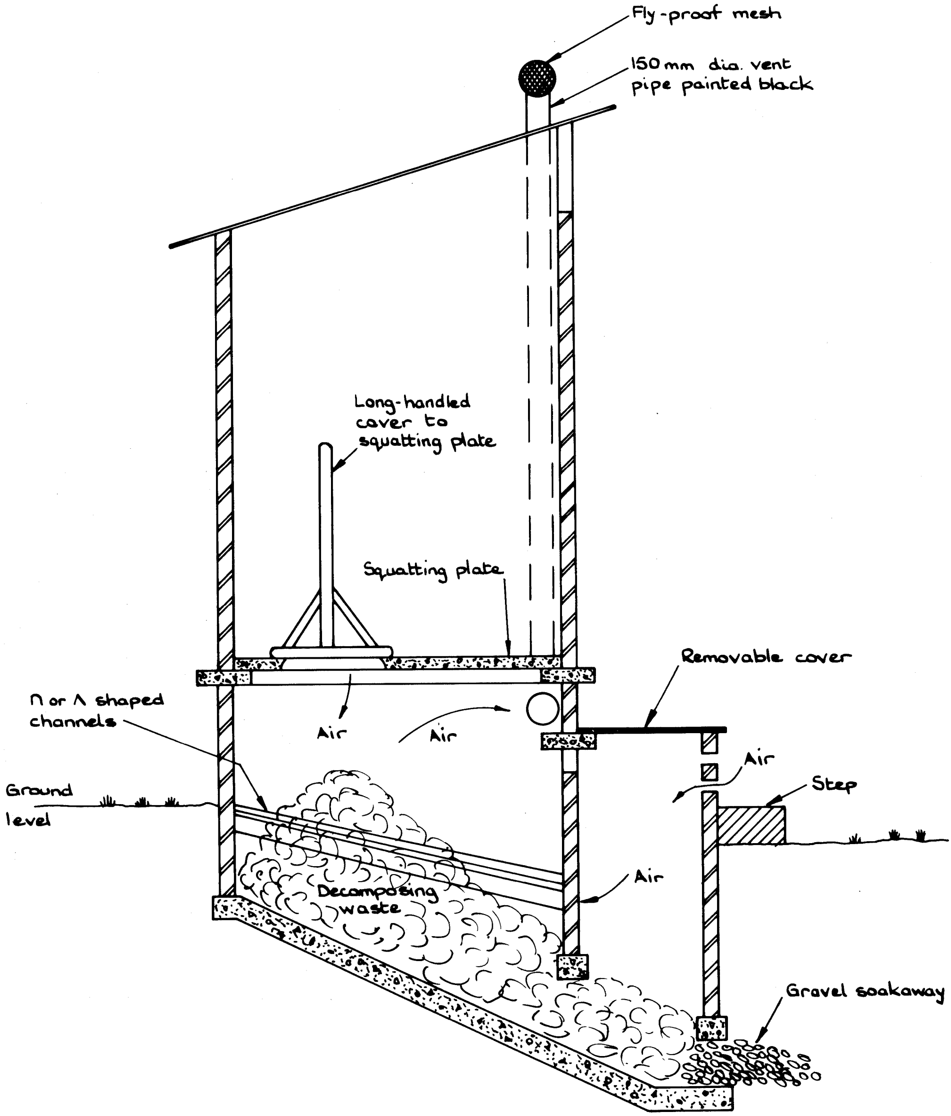


Fig. 10. A 'multrum'-type composting toilet for one family. This prototype design has not been tried in practice, but it well illustrates the principles of dry composting toilets. Household refuse is added to the excreta through the squatting plate, and the compost is removed from the bottom of the slope below the access cover.

forms of motorised cartage are possible including the vacuum truck system which, in conjunction with individual vaults, is widely used in the Far East (Figure 9).

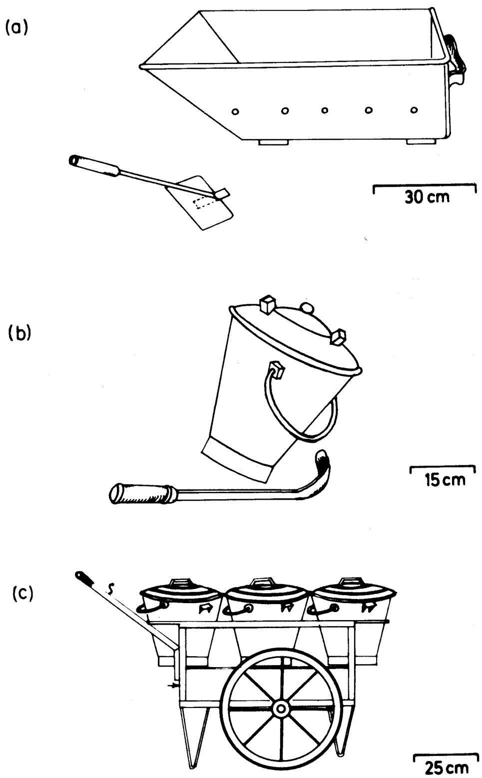


Fig. 11. Cartage equipment: (a) nightsoil container made from 24 gauge galvanised iron sheet, and scraper; (b) nightsoil bucket and scraper; (c) wheelbarrow for three to six buckets. (Designs by Department of Social Welfare, Ahmedabad).

2.5 TREATMENT

In some excreta disposal systems, the treatment of either nightsoil or water-borne wastes (sewage) may be required. A variety of treatment processes are available and their design under tropical conditions is described by Mara (1976).

Not all these processes are applicable to the tropics, however. In particular, trickling filters easily become anaerobic in hot climates, and create serious odour problems. They can also act as breeding places for certain pathogenic bacteria and large numbers of flies, become blocked with sludge, and require moving parts which frequently break down. They are not suitable for most tropical applications, least of all in small communities. The only method which will generally be relevant to the treatment of wastes on the small scale described in this booklet is the waste stabilization pond.

Waste stabilization ponds

Ponds may be used for the treatment of sewage or nightsoil and can be constructed for a small community (such as a school) or for a large city. Ponds allow treatment through natural biological and physical processes and require no mechanical parts or equipment. They are cheap and easy to construct and their operation and maintenance is more akin to gardening than to engineering. Their rate of operation increases with the ambient temperature, so that they are particularly well suited to tropical climates.

For small systems, three ponds in series are appropriate. The first pond would be a 'facultative pond' (combining both aerobic and anaerobic processes) whilst the subsequent ponds would be 'maturation ponds' which provide aerobic treatment and greatly reduce the numbers of pathogenic microorganisms in the sewage. The arrangement of typical pond systems is shown in Figure 12. The wastes flow by gravity from one pond to the next.

Ponds can receive sewage from a conventional sewerage system, or settled sewage from an aqua privy or septic tank, or nightsoil which is carted to them and sluiced into them down a ramp. In this last case, water must be added to the ponds to maintain water levels.

Two other methods are appropriate for the treatment of non-water-borne wastes such as nightsoil.

Anaerobic digestion

Nightsoil may undergo anaerobic digestion. Gas known as 'biogas' and consisting mainly of methane is produced, and may be used as a source of energy as described in Section 2.7. The digested sludge or 'slurry' may be used as an agricultural fertilizer.

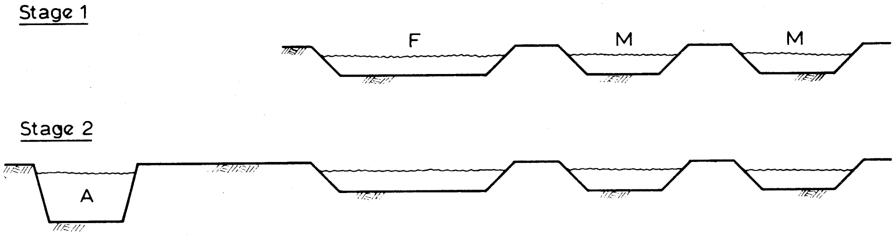


Fig. 12. Stages in the development of a waste stabilization pond system: F = facultative pond; M = maturation pond; A = anaerobic pond or septic tank. For small populations, septic tanks may replace the anaerobic pond. (From Mara).

Composting
Nightsoil may be mixed with organic wastes and refuse and composted. Composting takes place in piles or in pits, and not under water. If the compost is frequently turned, to allow air into it, it will not produce offensive odours. Temperatures of 50°-60°C are reached and efficient composting will take 1-4 months. This combination of time and temperature will cause most pathogens to be destroyed and will produce an inoffensive material suitable for agricultural use. A very thorough and readable account of the subject is given by Gotaas (1956).

2.6 DISPOSAL

There are various methods of getting rid of human wastes. Some of these are linked to re-use systems and will be discussed in Section 2.7.

Trenching
The disposal of untreated nightsoil is not normally advisable but it can be buried if necessary, in trenches at least 0.6 m deep. Nightsoil is placed in them to a depth of not more than 0.3 m, covered with tamped earth to make a small mound of earth over the trench, and then left for at least two years.

The chief advantage of the method is simplicity, although good supervision is required to ensure that the trenches are not filled too full of nightsoil. The disadvantages include the cost of land required, the possible contamination of ground water for water supplies and the depredations of domestic or wild animals. Some simple form of re-use such as composting will often be preferable to this.

Soakaways
Water-borne wastes on a small scale are most usually disposed of in soakaways. A soakaway is basically a pit or a trench filled with stones or given a lining through which water can seep. It simply allows the waste water to filter into the ground and disperse. At the same time some digestion will take place, aided by layers of microbiologically active slime which will build up around the soil particles. The size of a soakaway, and the area of land it requires, will be determined mainly by the volume of waste water produced. The siting of a soakaway must be carefully chosen to avoid the pollution of water supplies.

Discharge to streams
The other method for the disposal of water-borne wastes not connected to a re-use system is discharge to a stream, river, lake or sea. The key factors affecting the design of a discharge system are the quality and quantity of the sewage, the quality and the quantity of the water into which it is being discharged ('the receiving water'), and the other purposes for which the water may be used. In developing countries, many streams are used untreated as sources of domestic water, and there is a danger of polluting them with faecal pathogens. Discharge to streams and lakes is only relevant to small systems when the body of receiving water is very large, or is already so heavily polluted that it is never used as a

water source. The design of a discharge system should be left to competent water engineers, and is described in several standard texts on waste water engineering and water pollution control.

2.7 RE–USE

Human wastes are a valuable natural resource and should be re-used wherever practicable. There are essentially three different systems for re-use; biogas production, agriculture and aquaculture. The exact nature of a particular re-use system depends so much on local conditions that it would not be appropriate to go into detail here. However a brief discussion of each method is presented in order to make the reader aware of the possibilities.

Biogas

Nightsoil, mixed with animal wastes, can be used to generate methane, or 'biogas'. This technique is most commonly found in China and India. Figure 13 shows a typical biogas plant. In India it has been found that a biogas plant in which a family's excreta are supplemented with the dung from three or four cattle can provide the fuel needs for cooking and lighting for a family of 5 people. As the influent waste is diluted and fed into the digester, the effluent or spent slurry is released and channelled away for use as fertilizer.

A biogas plant requires careful control and is only appropriate where good operation and maintenance facilities can be guaranteed. Anyone contemplating constructing one should take advice from others with first hand experience and consult some of the technical literature. A very useful annotated bibliography has been prepared by Freeman and Pyle (1977).

Fertilizer

Both nightsoil and sewage may be used to enrich the soil. The direct application of nightsoil as an agricultural fertilizer has been practised for centuries in many parts of the world, but this practice involves very substantial health hazards to agricultural workers and to the consumers of the crops grown, and is not recommended. Nightsoil should be

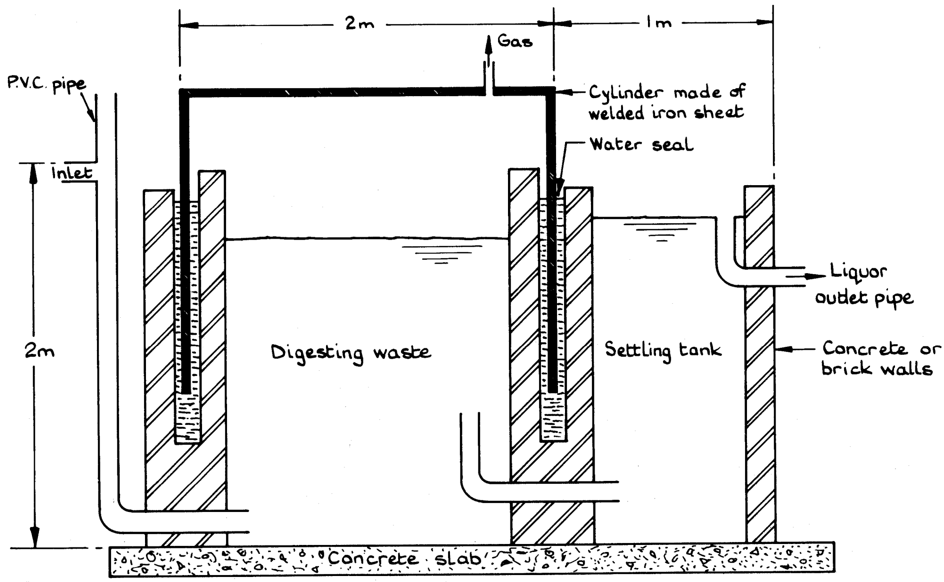


Fig. 13. One type of biogas digester. (From Solly).

Plate 4. Nightsoil is transported in bullock carts to fish ponds where it is poured into channels to run into the pond. (Photo: M. G. McGarry).

either digested, or composted with organic refuse and vegetable matter, before application to the land.

Similarly, water-borne wastes should not be applied directly in most circumstances. They should first be treated in waste stabilization ponds and the pond effluent used for irrigation. Spray irrigation involves a risk of the air-borne spread of pathogens and is not recommended. It is preferable from a public health viewpoint to use sewage effluent to irrigate crops such as trees or cattle fodder rather than crops intended for human consumption. It is especially inadvisable to use either nightsoil or sewage effluent to fertilize fruit, vegetables or any crop which may be eaten uncooked.

Aquaculture

Ponds containing human wastes are rich in aquatic life provided they remain in an aerobic condition. In particular, they support large blooms of algae. These conditions are perfect for the growth of certain types of fish, especially carp and tilapia. Fish productivities of 2–3 tons per hectare per year can be achieved in ponds enriched with excreta. Ducks will also thrive, in conjunction with fish, in such ponds.

It is possible to feed fish ponds with a certain amount of nightsoil brought in carts from a nearby community, or to locate latrines over ponds for the direct entry of excreta or better to grow fish in the maturation ponds in a series of waste stabilization ponds which are treating water-borne wastes. All these arrangements are commonly employed today, particularly in South East Asia.

The fish harvested may be used to produce high-protein meal for pig or poultry farming but more usually are sold for domestic consumption. However, if fish are for human consumption it is important that they are well cooked. If not, they may act as the main transmission route for a variety of pathogens, most notably the oriental liver fluke (*Clonorchis sinensis*).

CHAPTER 3 COMPLETE SANITATION SYSTEMS

3.1 INTRODUCTION

Now that the elements of a sanitation system have been described individually, we can examine complete systems which use various combinations of these elements. The combinations which we recommend are shown schematically in Figure 14. These will now be described in turn in more detail.

3.2 PIT LATRINES

Pit latrines are the commonest and most simple sanitation system. They are almost universally applicable in rural areas and are widely used in urban areas, although often not ideal. They are the cheapest system possible and the system most appropriate for self-help programmes in which individual householders are responsible for their own sanitation. Figure 14 shows schematically a basic pit latrine and a composting pit latrine. The major obstacles to pit latrine construction are population density, high water table, rock, sand and water contamination. These will be discussed in turn.

Population density

Pit latrines cannot be built where there is not enough space to dig and re-dig sufficient pits to receive the excreta of the whole community. In general, pit latrines should be located at least 6 m from any houses. Where populations are too dense, too many people will have to rely on too few pits; pits will not be re-dug often enough and the ground will eventually become saturated with human wastes. Pit latrines are therefore not appropriate in many cities or in large, high density villages.

High water table

Where the level of water in the ground is high, the construction of pits becomes very difficult, they tend to collapse in the wet season, and there is a danger of *Culex fatigans* mosquitoes (which in some parts of the world carry a disease called filariasis) breeding in pits with high water levels. In such circumstances a built-up pit is appropriate as shown in Figure 15. The built-up plinth may be about 1 m high and the water-tight lining of concrete or sealed brickwork should extend down at least 0.6 m below ground level.

Rocky ground

Pit latrine construction becomes both difficult and expensive in rocky ground. There is no easy answer to this except that householders wishing to build pits in rocky areas may appreciate assistance from the local public works department with mechanical diggers. The temptation in rocky ground is to build very small pits, which quickly become filled so that more pits are required. This temptation should be resisted and the principle of building pits as large as possible should apply even more strongly in rocky areas, because the fluids in a pit will usually seep more slowly into rock than they would into soil.

Sand

Pits dug in loose and unconsolidated soils (e.g. sand or fine grained alluvium) will collapse. They will therefore need to be supported as in Figures 15 or 16.

Water contamination

The placing of wastes in pits will always present the danger of polluting water sources – particularly wells located nearby. As a general rule, pit latrines should not be built within 30 m of a well or other drinking water source and should not be located uphill from the water source. The danger of pollution is increased if the pit base is below the water table or if the soil contains fissures and cracks. The danger is also greater where large volumes of water are extracted from the well. In areas where pit latrines are located near boreholes serving large populations, the water quality needs to be frequently checked for the presence of faecal bacteria and nitrates.

3.3 BUCKET AND CARTAGE SYSTEMS

Figure 14 shows schematically two alternative forms of bucket latrine system. In one the

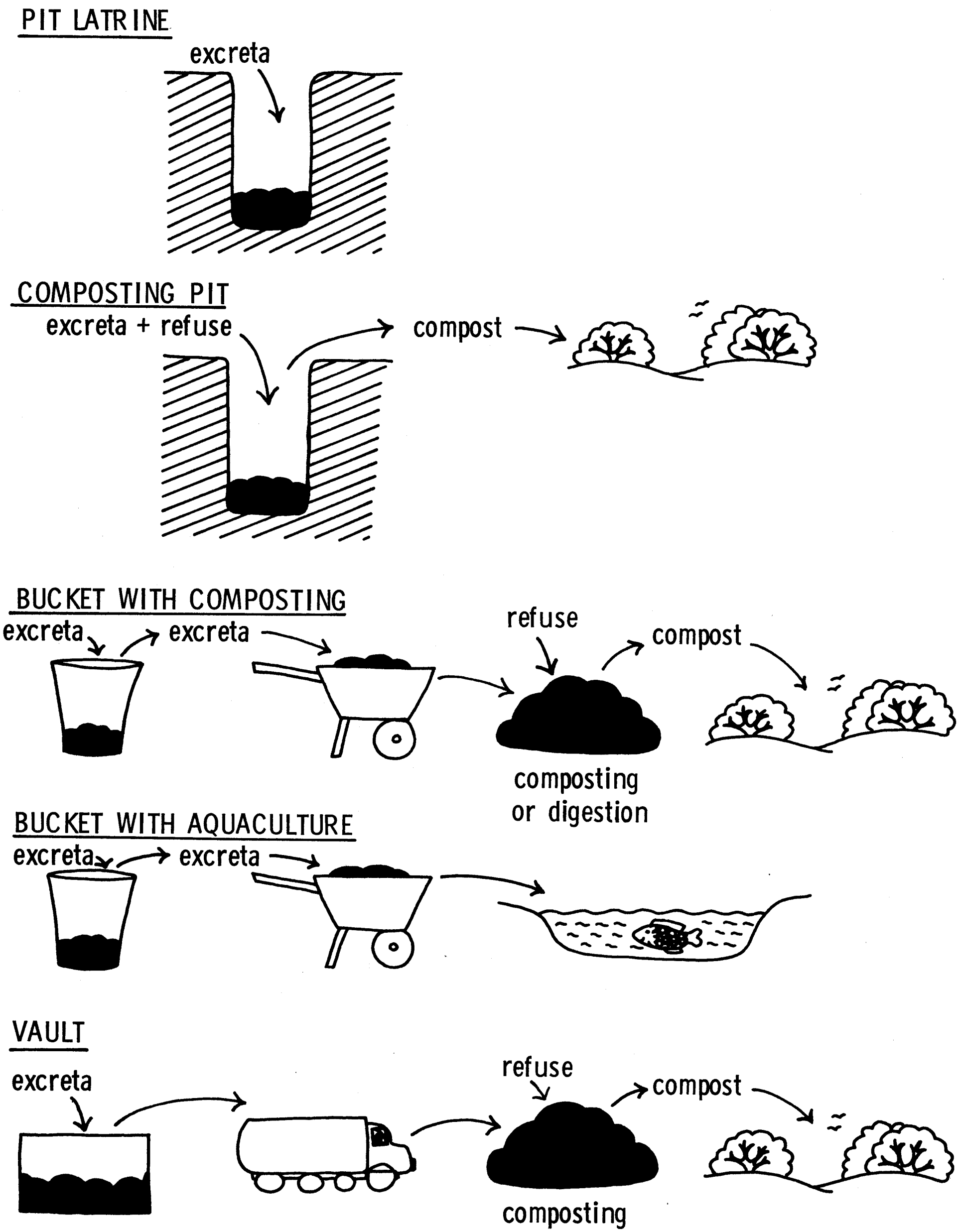
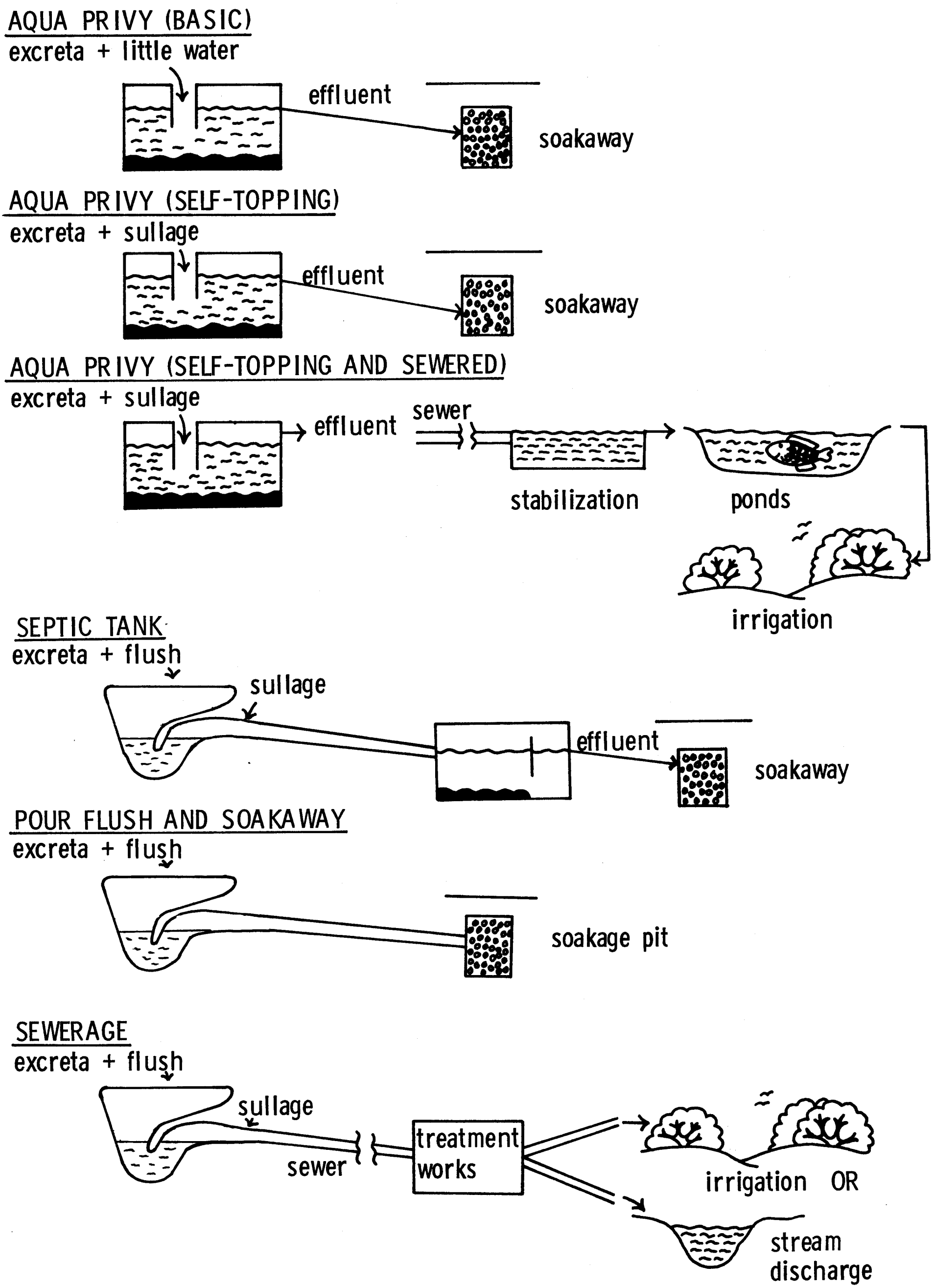


Fig. 14. Pictorial representations of various excreta disposal systems.

(a) 'Dry' or nightsoil systems.



(b) 'Wet' or sewage systems.

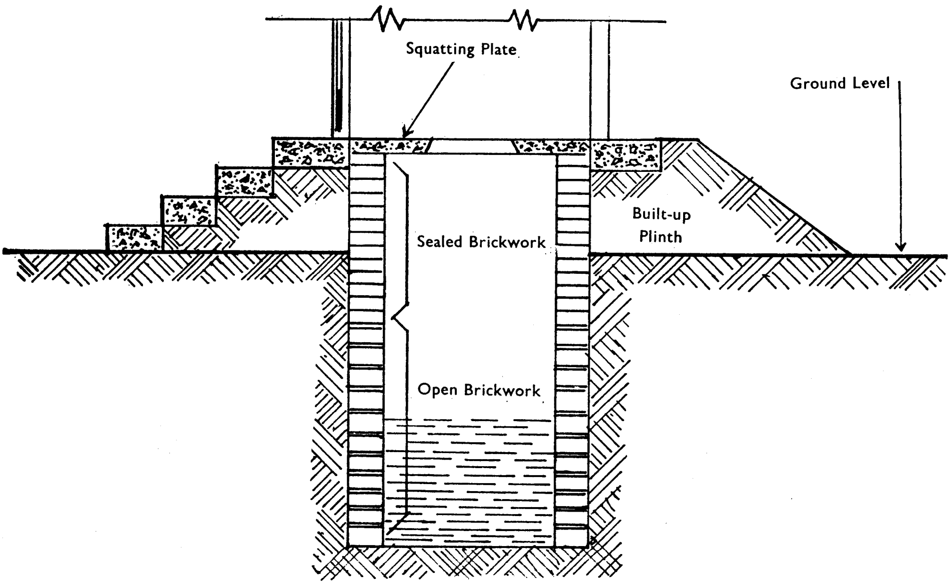


Fig. 15. A built-up pit latrine suitable for areas where the subsoil water or rock is near the surface. The type of brick lining shown is also useful in soils where the sides of the pit need support.

nightsoil is composted and put on the land, while in the other the nightsoil is used to enrich fish ponds. These, and other variations of the bucket system, are widely used but are generally very unhygienic.

The act of emptying the bucket into the barrow or cart typically involves spillage and the area becomes a centre for fly breeding and cockroaches. The same occurs at the depot where the carts are emptied for transportation in trucks or for treatment, composting or agriculture.

In general, all cartage systems which require removal of the nightsoil by hand from one vessel (e.g. the bucket) to another (e.g. the cart) are extremely unhygienic and offensive. Motorised systems employing vacuum trucks, on the other hand, can be perfectly hygienic and aesthetically acceptable and are used in some modern and wealthy communities. They are more expensive, however.

Ideally, buckets should be sealed with a lid and carried to the depot before being emptied – a new disinfected bucket being substituted. The practice of emptying the bucket and immediately replacing it should be rejected. At the depot, buckets should be washed thoroughly and painted with a disinfectant. It may be helpful to have a colour code so that all buckets collected on Mondays are red, for instance, and all replacement buckets on that day are yellow. This will help to distinguish the buckets which have been disinfected from those which have not.

A bucket system can work under situations of tight institutional control, where all operations are closely supervised. It should be regarded as a temporary measure suitable for camps, for instance, while more permanent installations are being constructed.

3·4 VAULT AND VACUUM TRUCK SYSTEMS

The next system shown in Figure 14 is the vault and vacuum truck arrangement. While this is a very satisfactory system it is appropriate only on a fairly large scale due to the financial and organisational problems associated with running a fleet of trucks. It is a system only appropriate for a town or city with an efficient and established municipal administration, and is thus outside the scope of this booklet.

3.5 AQUA PRIVY SYSTEMS

Aqua privies require less water and are usually cheaper than any other system with the same standard of protection from smells, flies and disease transmission. As long as an aqua privy is kept topped-up with water, there are few things to go wrong with it. It is basically a septic tank directly beneath a latrine. Its advantages over a separate septic tank are that it uses less water and less land, and that it does not require solids to be flushed along a pipe and so is less liable to blockage.

Figure 14 illustrates three alternative types of aqua privy system. The commonest cause of failure of a basic aqua privy (Figure 6) is failure to pour into it a couple of buckets of water a day to maintain a seal. It has been found that where public taps are combined with individual aqua privies, householders are very reluctant to carry water from the tap to pour down the privy unless water is required for anal cleansing. It is for this reason that the self-topping aqua privy (Figure 17) was devised. This is linked to washing facilities so that water used in the same block for washing purposes drains into the aqua privy tank, to ensure a sufficient flow of water and maintain the seal. The third type shown in Figure 14 is a system in which aqua privies are connected to small diameter sewers. The sewered aqua privy has been tried in Zambia with disappointing results due to the blockage of the sewers. In any case, a sewered aqua privy has to be part of a sewerage system and therefore is beyond the scope of this booklet.

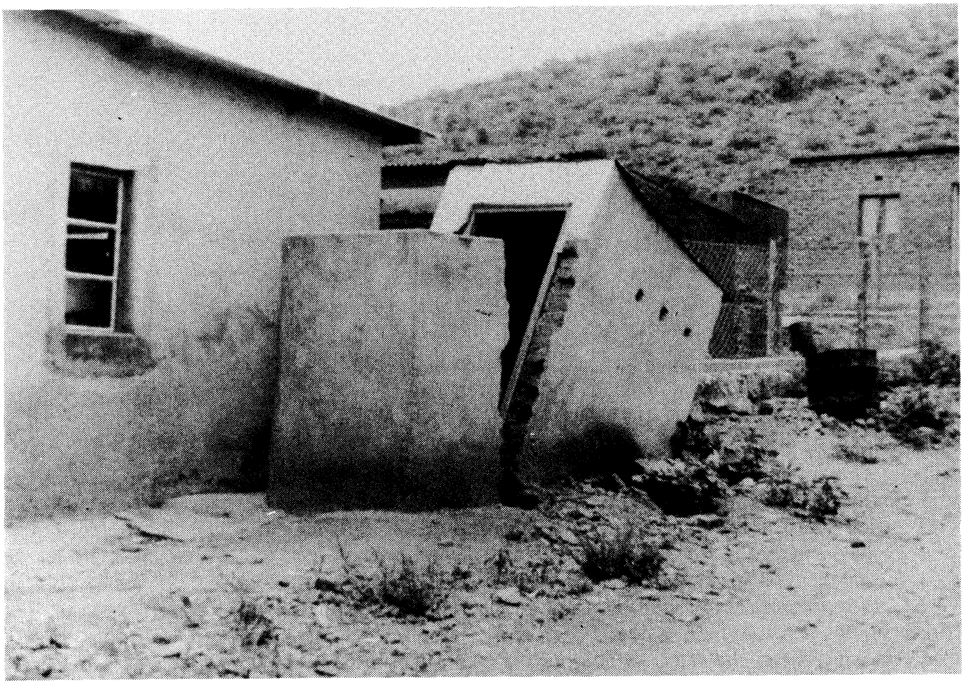


Plate 5. A collapsed pit latrine. The superstructure is unnecessarily massive and was placed on inadequate foundations above an unsupported pit. Figure 16 shows a more correct design to prevent the collapse of pit latrines. (Photo: R. G. Feachem).

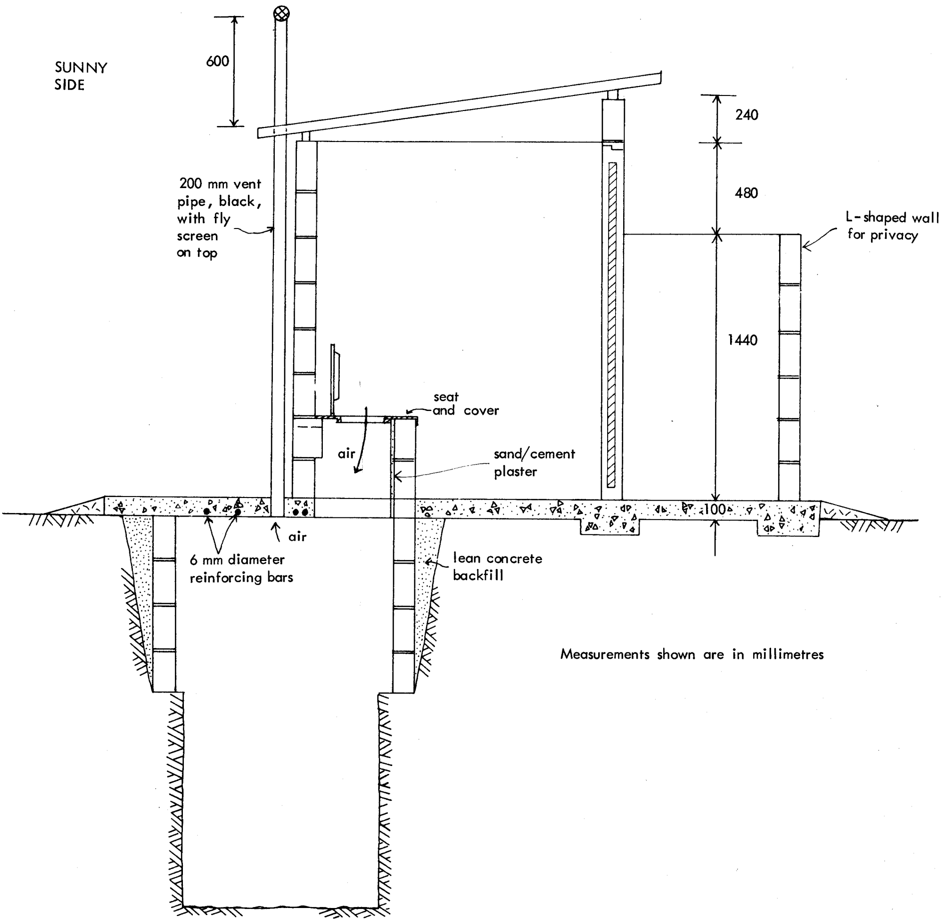


Fig. 16. Supported pit latrine with ventilation. (From a drawing by R. A. Boydell).

Aqua privies have worked much better in parts of the world where water is used for anal cleansing (as in Muslim countries) than where sticks, stones or heavy paper may be used (as in parts of Africa). No refuse of any kind should be placed in an aqua privy. It would cause premature filling of the tank and failure of the privy. Where water is used for anal cleansing it has the effect of eliminating the need for paper etc., of keeping the squatting slab and chute clean and of providing the necessary water to flush through the tank and maintain the seal.

3.6 SEPTIC TANK SYSTEMS

The next system illustrated in Figure 14 is the septic tank system. Septic tanks can be used for populations of over 300 but they are most commonly found on individual dwellings. In the tropical cities of the world, houses in relatively high-income, low-density areas not having a sewerage system frequently employ individual septic tank systems. The septic tank often takes all waste water from the house and thus needs a substantial soakaway (Section 2.6). This need for adequate soakage makes the system unworkable in high density areas. The toilet may be of the cistern flushed or the pour flushed variety (Section 2.2) although the cistern flush is more usual. Clearly, a plentiful supply of piped water is required for a cistern flushed system and this requires a larger and more expensive tank and soakaway. Figure 18 shows a layout for a cistern flushed, septic tank system serving two bungalows. A septic tank may also be joined to the kind of communal, cistern flushed unit illustrated in Figure 4.

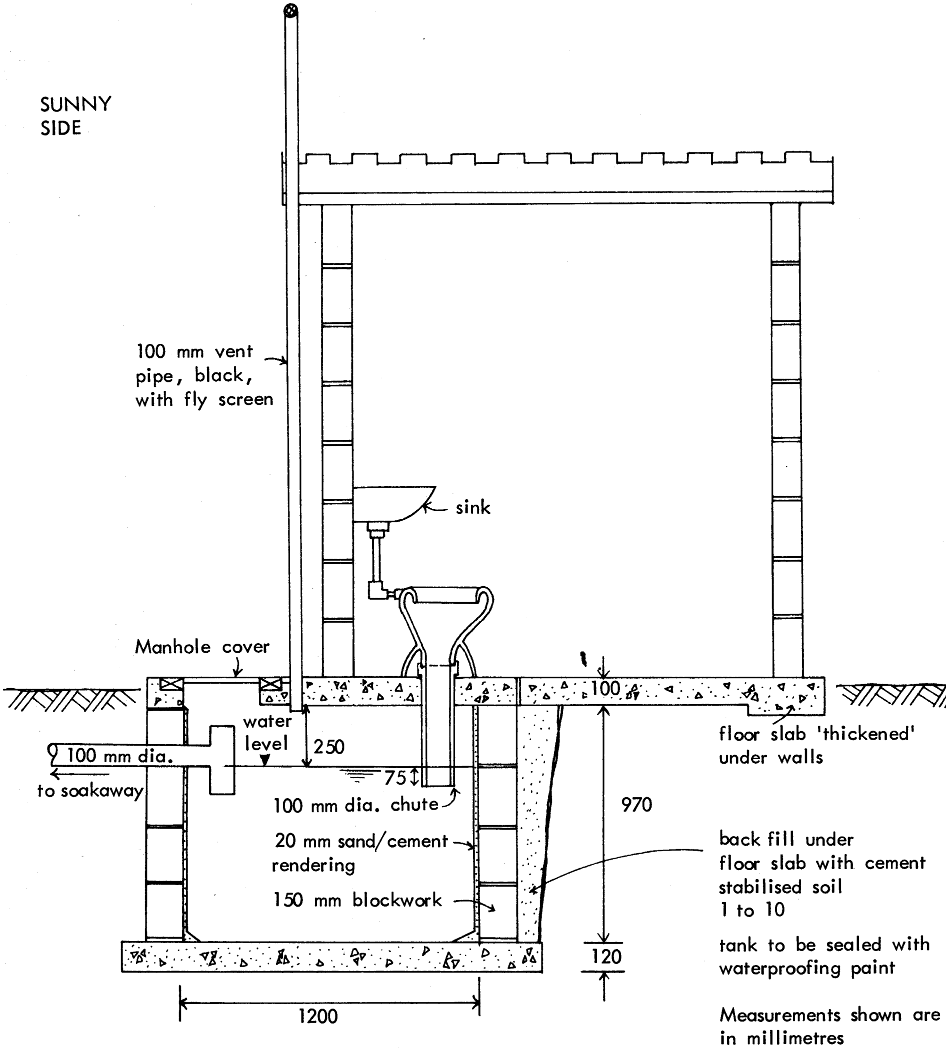


Fig. 17. Self-topping aqua privy. It will usually be preferable to have a large sink on the outside wall rather than a small one inside. The sink need not be connected to a water supply but if not, water must be nearby to encourage the use of the sink for washing clothes. The seat may be replaced by a squatting slab. (From a drawing by R. A. Boydell).

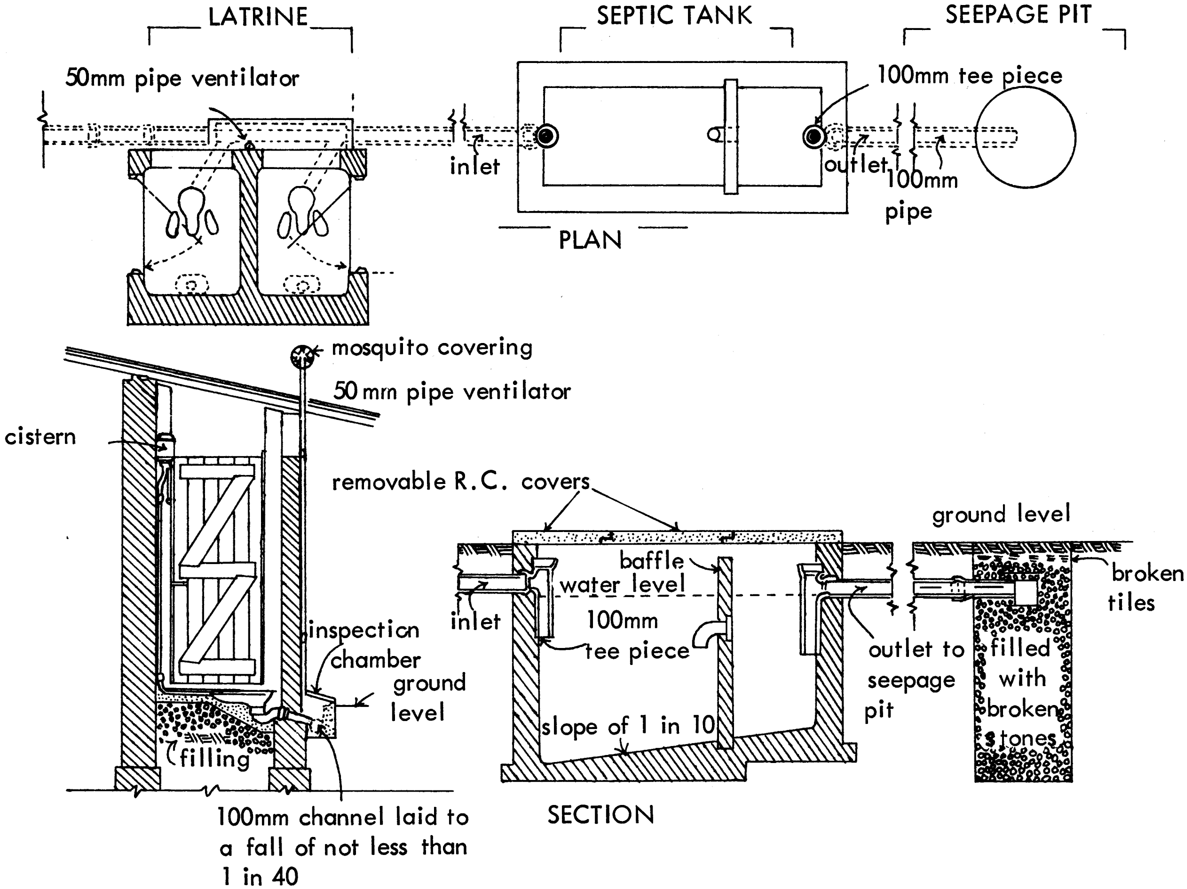


Fig. 18. Cistern flush latrines with squatting plates for two families. The sewer leads to a septic tank and from there to a seepage pit.

3·7 COMBINED SHOWER/LATRINE

It is possible with the aqua privy or the septic tank systems to incorporate a shower into the latrine. A typical design is shown in Figure 19. This has the advantage of keeping the bowl or squatting slab clean and of maintaining a good flow through the pipes, aqua privy or septic tank. However, the capacity of the tank and soakaway will have to be larger to take account of this increased flow of waste water and the combination of shower and latrine may be culturally unacceptable.

3·8 POUR FLUSH TO SOAKAWAY SYSTEMS

Figure 14 illustrates the alternative of linking a pour flush directly to a soakaway. A design is shown in Figure 20. This system is most commonly found in India and Sri Lanka and is most suitable for areas where water is used for anal cleansing. In other areas, people are unlikely to carry water to operate them and so water must be close to or inside the latrine. Figure 3 illustrates possible designs for the pour flush bowl. The pipe connecting the bowl to the pit should be straight and not more than 8 m long. The design of the soakage pit will be discussed in Section 4.5. The larger the pit the better.

3·9 SEWERAGE

A full sewerage system is associated with large communities and is outside the scope of this booklet. It is expensive and uses large volumes of water. Many countries have found themselves financially unable to construct sewerage systems for the majority of their populations.

3·10 SELECTING YOUR SYSTEM

The final choice of which excreta disposal system is adopted in a particular case will depend on many factors and no easy guide can be presented. Table 2 gives some of the important relative features of the systems discussed in this booklet.

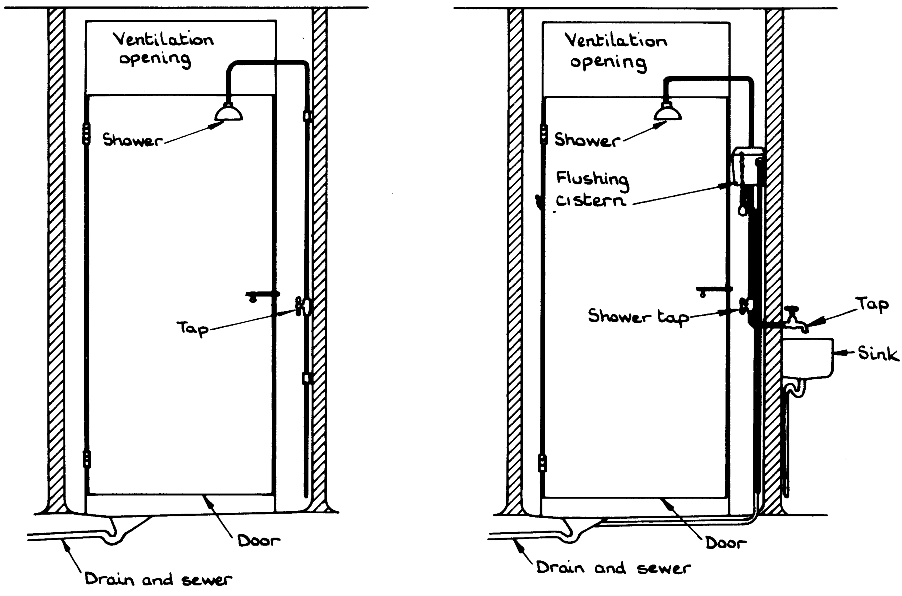
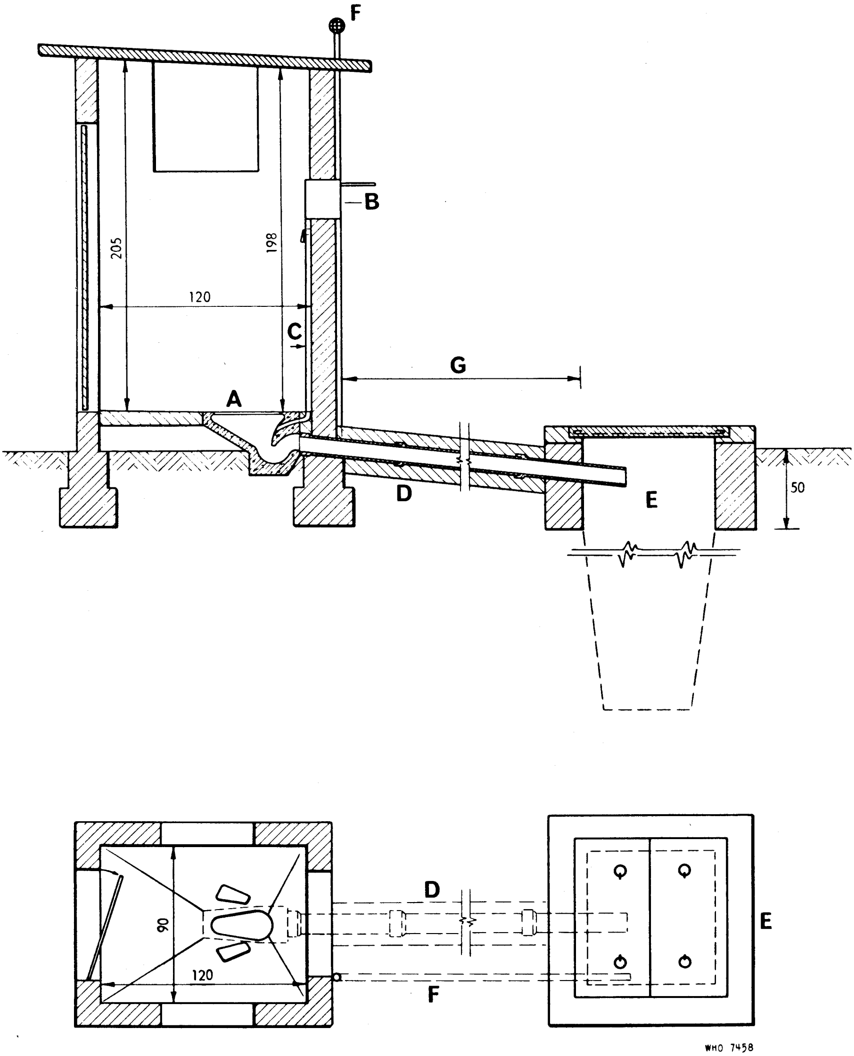


Fig. 19. A combined shower and latrine, showing on the left a shower in a pour-flush privy and on the right a shower in a cistern flushed privy. The water pipe may also supply a tap over the sink in an adjacent kitchen. The wastes from the sink may discharge into the septic tank.



Measurements shown are in centimetres

A = Water-seal bowl with S trap
B = Water tank, filled by hand and provided with plug cock and overflow pipe
C = Water pipe leading from tank to bowl for flushing purposes
D = Drain pipe embedded in concrete leading to seepage pit
E = Seepage pit
F = Ventilation pipe for pit
G = Distance between bowl and pit should be as short as possible

Fig. 20. Pour-flush and soakaway system. (From Wagner & Lanoix).

The final decision will depend to a large degree on previous experience, both good and bad, of sanitation systems in the area. This will dictate not only the building skills which may be locally available but also the prejudices and preferences of the users of the new system.

TABLE 2: **Comparison of Several Sanitation Technologies**

Sanitation System	*Rural Application*	*Urban Application*	*Construction Cost*	*Operation Cost*	*Ease of Construction*	*Water Requirement*	*Hygiene*
Pit latrines	Suitable in all areas	Not in high density suburbs	Low	Low	Very easy except in wet or rocky ground	None	Moderate
Bucket and cartage	Suitable	Suitable	Low	High	Easy	None	Bad
Vault and vacuum truck	Not suitable	Suitable where vehicle maintenance available	Medium	High	Requires skilled builder	None	Moderate
Aqua privies	Suitable	Suitable	High	Low	Requires skilled builder	Water source near privy	Good
Septic tanks	Suitable	Suitable for low-density suburbs	Very high	Low	Requires skilled builder	Water piped to privy	Excellent
Pour flush and soakaway	Suitable	Not suitable	High	Low	Requires skilled builder	Water source near privy	Good
Sewerage	Not suitable	Suitable where it can be afforded	Very high	Medium	Requires experienced engineer	Water piped to privy	Excellent

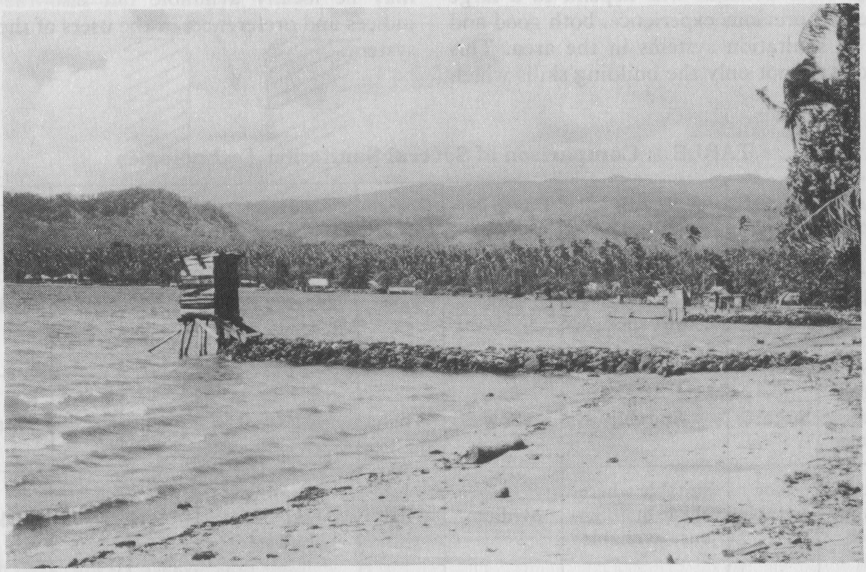


Plate 6. An over-sea latrine. Excreta is frequently washed back onto the beach and there is obvious risk to bathers. (Photo: Ross Institute).

Plate 7. The back of four ROEC offset pit latrines in Botswana. The large ventilated pits are under the concrete slabs. The vent pipes should be black. (Photo: R. G. Feachem).

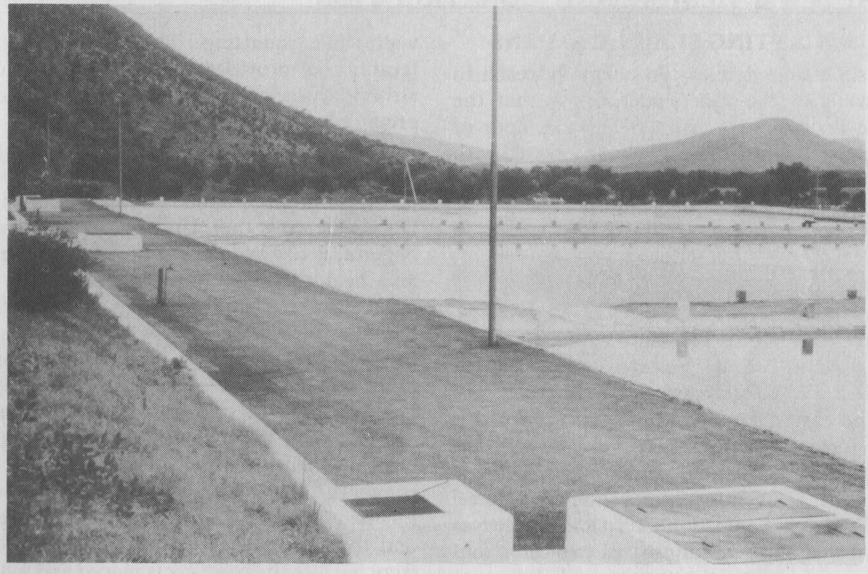


Plate 8. Well kept anaerobic ponds treating abattoir effluent in Botswana. (Photo: R. G. Feachem).

Plate 9. A biogas plant at a monastery in Thailand. Biogas plants are most suited to small rural institutions (such as schools, hospitals, prisons, monasteries, larger farms or communes) rather than individual households. (Photo: D. J. Bradley).

CHAPTER 4 DESIGN AND CONSTRUCTION

4.1 SQUATTING SLABS AND PANS

The squatting slab should normally reach to the walls of the superstructure, so that the whole floor can be easily cleaned. A floor of damp soil in a latrine can become infected with hookworm larvae. Various materials may be used, including:

(i) reinforced concrete
(ii) reinforced concrete with brick filler
(iii) wood

Concrete slabs are the most usual, the most long-lasting and generally the most satisfactory. Very importantly, concrete slabs are the easiest kind to keep clean. If wood is used, it must of course be termite-proof.

Concrete slabs should always be reinforced with steel. The reinforcement should be of steel bars at least 8 mm diameter, and spaced as shown in Figure 2, running in two directions across each other in a square grid. It is very important that the bars should be embedded in the concrete and not visible in the top or bottom of the slab. This can be ensured by placing the concrete 25 mm deep before positioning the bars on it, and then placing the remainder of the concrete on top. In the finished slab, the bars should preferably be nearer the bottom than the top (Figure 2).

Slabs may be square, round or rectangular. A 1 m by 1 m square is a common size. A concrete slab of this size, with a thickness of 65 mm, will weigh about 140 kg. An advantage of a round slab is that it may be rolled around the site.

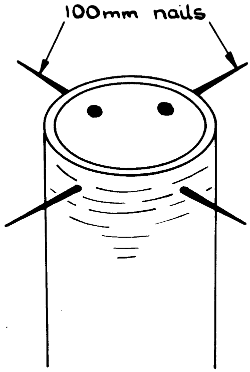
A minimum thickness for a well-made reinforced concrete slab is 60-70 mm at the edge and 50 mm at the centre. Sloping the surface of the slab down towards the hole and providing raised foot-rests makes it easier to clean. The shape of the hole and foot-rests can vary. A typical arrangement is shown in Figure 2. The hole should have a length of at least 360 mm to prevent soiling of the floors. The width should be less than 180 mm to prevent small children falling through. The distance from the back of the hole to the back wall of the superstructure should be more than 150 mm to prevent the need to lean against the wall while squatting. The hole should preferably be provided with a lid or cover, although users in some countries may not be prepared to touch it.

There are a variety of ways of manufacturing the squatting slab and chute for an aqua privy. A simple method, developed by P. A. Oluwande of the University of Ibadan, Nigeria, is to have the chute cast into the slab and held there by four 100 mm nails. The chute may be a suitable length of 150-200 mm diameter pipe. Either asbestos cement pipe or bamboo are appropriate. Four holes are made at 25 mm from one end of the pipe and four 100 mm nails inserted (Figure 21). The end of the pipe with the nails through it is then cast into the slab to produce a composite unit shown in section in Figure 21. The formwork for the base of the slab is placed over a trench, and the pipe hangs down through it into the trench while the concrete is placed and allowed to set.

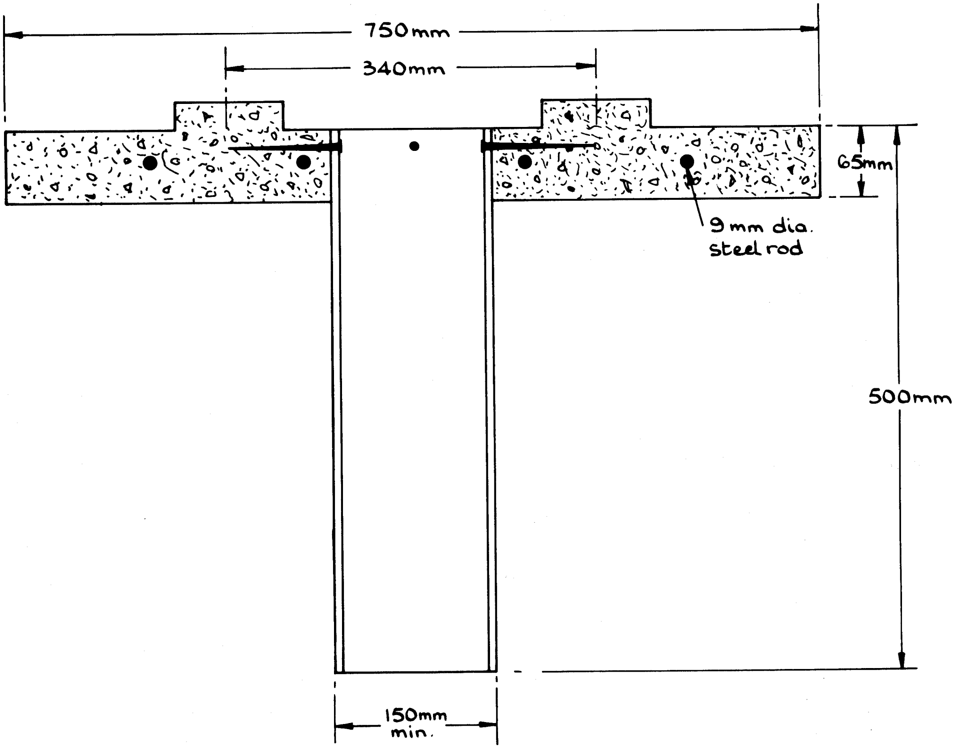
If a pour flush pan is used, the water seal should not be more than 15-25 mm (Figure 3). The seal has to be carefully designed so that flushing is possible with small volumes of water. If the water-seal and pour-flush is discharging into a sewer pipe (perhaps leading to a septic tank or seepage pit) the length of that sewer should not exceed 8 m and it should be straight due to the limited carrying power of the small volume of water used for flushing. A 100-150 mm pipe laid at a slope not less than 1 in 40 is recommended. A water tap should be located inside, or very close to, the latrine. If there is a danger that a tap inside the latrine may be used for drinking water, an alternative should be provided.

4.2 PIT LATRINES

In general, pit latrines should be located more than 6 m away from houses and 30 m from water sources. A typical pit latrine is shown in Figure 5. The pit may be 3 to 7 m deep and about 1 m across and should have almost vertical walls. However, any excavation below 1 m deep can be dangerous work, and pits should not be dug more than 3 m deep by



TOP OF CHUTE PIPE



SECTION THROUGH SLAB AND CHUTE

Fig. 21. Simple method of casting a squatting slab and chute for an aqua privy. (From Oluwande).

inexperienced workmen. In some conditions a circular pit will be less likely to collapse than a square one. If many pit latrines are to be built it may help to use a wooden frame which can be placed on the ground to mark out the dimensions of each pit. In sandy or unstable soils the sides of the pit must be supported to prevent them falling in (Figures 15 and 16). Wood, concrete, burnt brick or an old oil drum may be used for this, but the lining should not prevent seepage of fluids into the ground. In rocky ground, mechanical diggers may be required to excavate the pit.

It is better if the pit latrine is wet and has standing water at the bottom, since this will promote digestion of the wastes and delay the filling of the hole. This can be assisted by plastering the floor and bottom part of the walls with mortar. But the water level should not be too high, or serious odour and insect breeding problems will arise. Particularly important is the possibility of *Culex fatigans* mosquitoes (which transmit filariasis in some parts of the world) breeding in pit latrines with high water levels.

In general, pits should be built as large as possible. As a rough guide, the pit volume may be calculated as at least 0.06 m^3 per person for every year of anticipated life. Thus, a big pit 1.3 m in diameter (or 1 m square) and 3 m deep may serve a family of five for 6 years before it becomes two-thirds full. However, the working life will be very considerably reduced if solid non-decomposable materials are used for anal cleansing (e.g. rocks or cement bags) or if domestic refuse is added to the pit.

Pit latrines should be built to last as long as possible and should have well-made surface structures. At ground level a solid, impermeable base should preferably encircle the opening of the pit (Figure 5). Such a base serves as a foundation for the floor of the latrine, and prevents the emergence of hookworm larvae and the entry of surface water, insects and small animals. This base should be made of concrete, stabilised soil (i.e., sandy-clay soil thoroughly mixed with 5% to 6% cement and rammed into a brick mould when the soil is very slightly damp), puddled clay, stone or brick (sun-dried or burnt) masonry, or termite-resistant logs. The spoil from the pit should be rammed to form a plinth extending 1 metre around this base (Figure 5).

If possible, pieces of sacking, soaked in motor oil, should be laid down to cover the area of the plinth and base, with their edges hanging down by at least 300 mm into the pit. These will prevent the emergence of flies hatched from the excreta in the pit, because the grubs have to burrow into the sides of the pit before they emerge at the surface as adults. This sacking is then covered by the floor of the latrine; outside the walls of the superstructure, it is covered with well rammed earth.

On the plinth and base is placed the floor of the latrine. A reinforced concrete slab or squatting plate makes the best floor. Its upper surface should be finished smooth in cement rendering and should be dressed with two coats of a 5% solution of silicate of soda (water-glass) to prevent the concrete absorbing excreta. Timber is sometimes used for flooring but it must be termite resistant (either naturally or treated to make it so), for a floor that is liable to collapse is hardly likely to make the latrine popular. Children, especially, are often afraid of falling into pit latrines, and the floor should be strong and firmly supported. Concrete slabs of the necessary size are heavy and it is sometimes an advantage to cast them at the site.

The superstructure is placed on the plinth and there should be no earth exposed between its walls and the edge of the squatting plate. Any space between should be filled in with smooth-finished cement. The door of the latrine should open inwards and the walls should be high enough for privacy, but should stop 300 mm below the roof so as to provide good through ventilation. It may help if you can design the superstructure so that it can be easily moved to a new site when the pit is full. Further details of construction techniques are given in Wagner and Lanoix (1958).

Modified pit latrines

Various forms of modification to the basic pit latrine are possible. The walls of the pit may be supported to prevent collapse, the squatting slab may include a pour flush water seal,

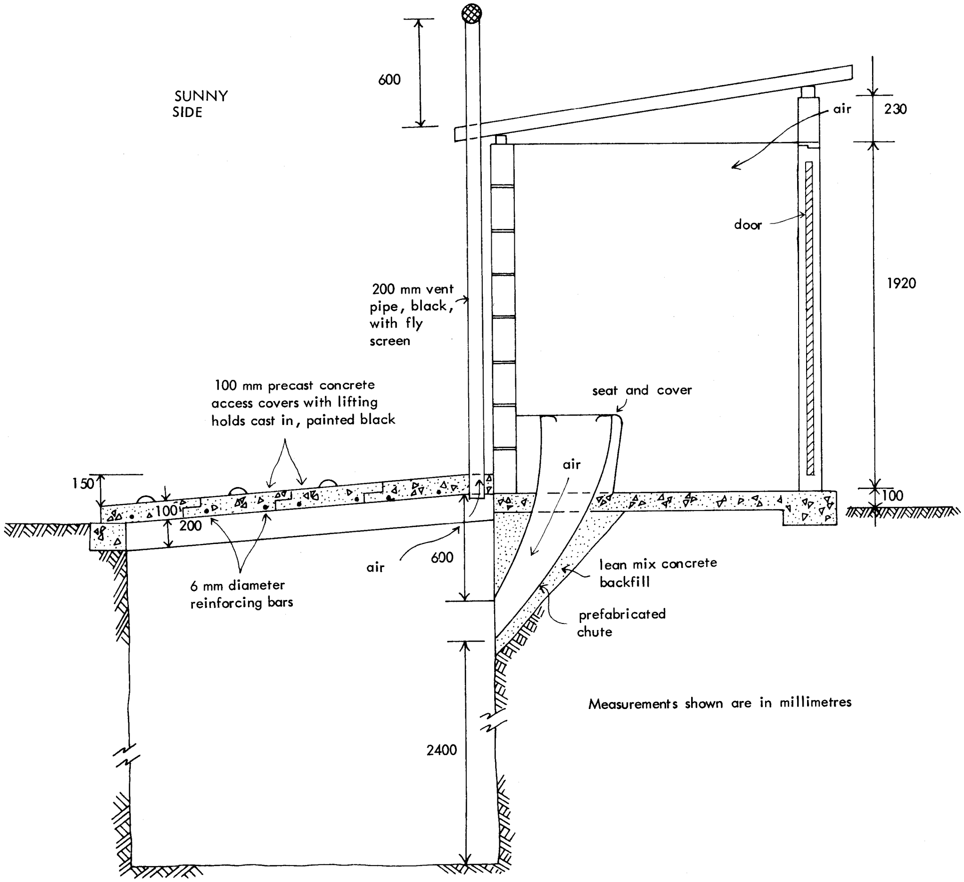


Fig. 22. A ROEC pit latrine. (From a drawing by R. A. Boydell).

and the pit latrine may be fitted with a vent pipe to prevent odours being released via the seat or squatting slab (also shown in Figure 16). The vent pipe should be 150-200 mm. diameter, and should be painted black and on the sunny side of the latrine. The pipe will be warmed by the sun, so that odours rise up it, and a downward draught will be encouraged to flow through the squatting slab or seat. A useful addition is a cover, such as the one shown in Figure 10.

The pit may be displaced to one side so that the excreta are introduced into the pit via a chute (Figure 22). This type is generally known as a ROEC (Reed Odourless Earth Closet) and provides an extremely satisfactory toilet provided a black vent pipe is fitted to the pit and exposed to the sun. The only major problem with the ROEC toilet is the breeding of flies in the upper part of the chute. This is reduced by ensuring that the seat or squatting slab has a lid which is kept closed when not in use, and by cleaning the chute daily with a long-handled brush. The lid should have small holes in it to facilitate a downward draught through the chute.

Composting pit latrines

A further modification of either the basic pit latrine or the ROEC is to provide two chambers, of brick or concrete. Figure 23 shows a latrine of this type, suitable for one

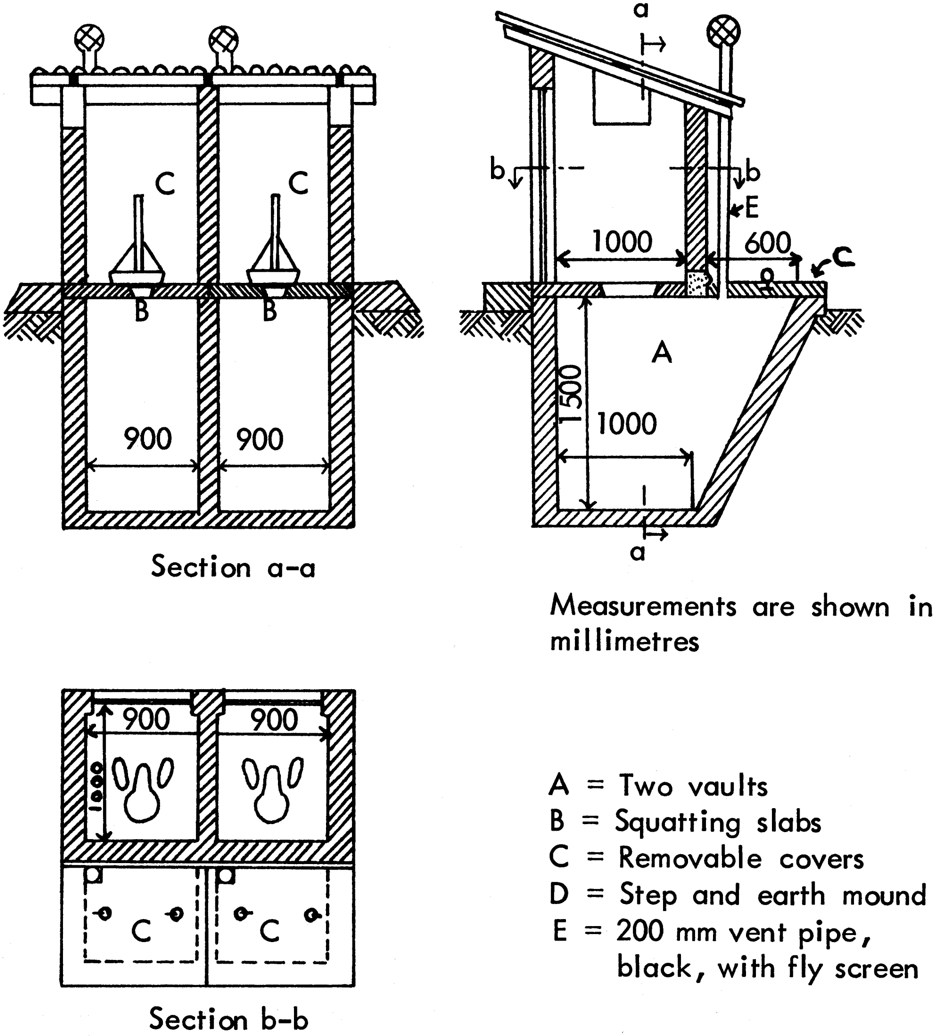


Fig. 23. Double-vault composting latrine suitable for single family. (From Wagner & Lanoix).

household. One chamber is used until partly filled, when it is filled with earth and sealed and the other is used. When the second chamber is full, the contents of the first one are removed and used as agricultural fertilizer. It is advisable to add organic domestic refuse, sawdust or ashes to composting pit latrines of this kind. The composting takes place anaerobically, and requires several months to make the compost safe for use in agriculture. Even then, it should be used carefully (Section 2.7).

There is some uncertainty about the exact design and operation of double vault composting latrines. In Vietnam, where they are widely used, urine is excluded, ash is added and the vaults are sealed when they are full. It is uncertain to what extent urine exclusion is essential and whether drainage could be used to remove urine. The addition of some source of carbon (ash, sawdust or vegetable wastes) is essential, but it is uncertain exactly what additions are most favourable to rapid composting or how these affect the design of the vaults. Composting is discussed in detail by Gotaas (1956).

Bored hole latrines

A bored hole latrine is a deep, narrow pit latrine. It is usually up to 6 m deep and about 400 mm in diameter. It is excavated with a hand auger or mechanical drill (Figure 24). Its volume, and therefore its life span, are typically less than those of a dug pit latrine and, because of its greater depth, the risk of ground water contamination is greater. It is difficult to line and liable to collapse. It is also liable to fouling of the side walls with excreta and to fly breeding on the fouled walls. It is, however, faster to construct in large numbers and requires a smaller slab than a dug pit. It is particularly appropriate following disasters where large numbers of latrines must be rapidly constructed.

4.3 AQUA PRIVIES

An aqua privy requires a seal to prevent odours, flies etc. rising from the tank. The simplest and most usual way to ensure this is to fit a chute (a vertical pipe) below the squatting slab, with its bottom 100-200 mm below the water level in the tank (Figure 6). This means that the tank must be kept full, because if the water level falls, the seal will be broken. One way to avoid the need for this is to use a pour flush water seal instead of a chute (Figure 25), but this obviously requires local familiarity with the pour flush system, appropriate anal cleansing habits and a tap in or near the privy.

Aqua privies, then, need water added to them daily to maintain the seal and to cause a flow through the system. On the basic aqua privy (Figure 6) this is achieved by simply pouring a bucket of waste water down the chute from time to time. At least 5 litres should be added per user per day.

A modified aqua privy, known as a self-topping aqua privy (Figure 17), ensures that water used in the same block for washing purposes finds its way into the aqua privy

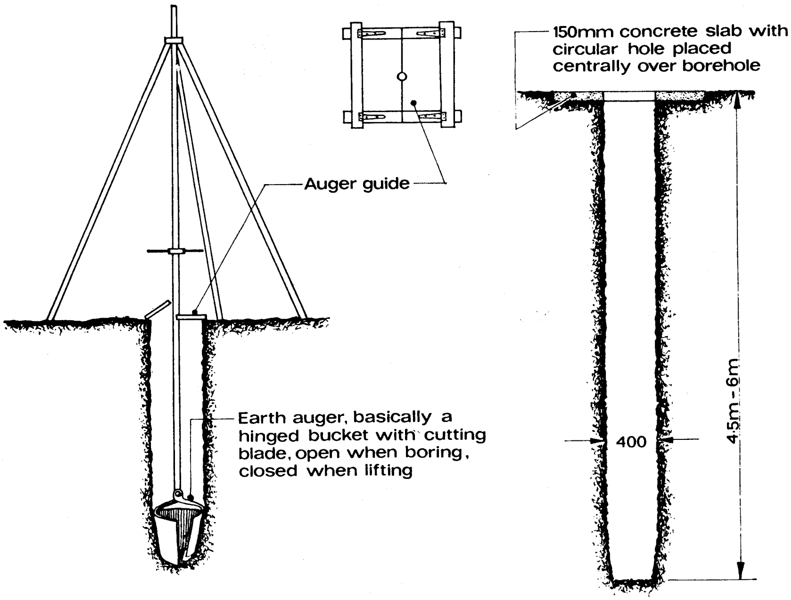


Fig. 24. Construction of a bored-hole latrine. (From the Manual of Army Health).

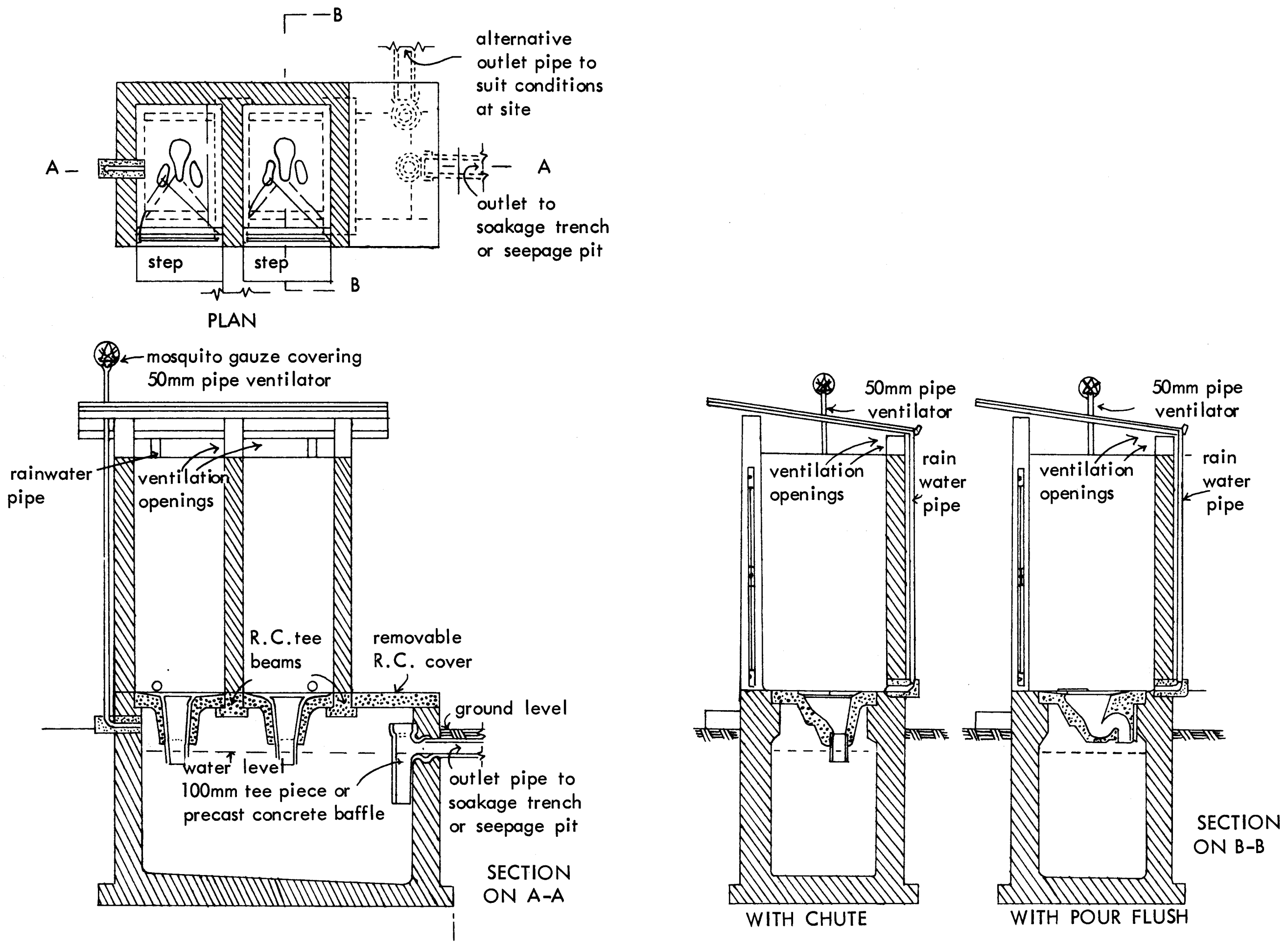


Fig. 25. An aqua privy for two families. Rainwater is piped from the roof into the tank to help maintain the water level.

tank. It is a good idea to link aqua privies, whether communal or individual, to washing facilities so that a flow of water into the tank is guaranteed.

A compromise is to have a basic aqua privy with the rainwater from its roof feeding into the tank (Figure 25). This will be no help in areas with a pronounced dry season, however. It must be remembered that the design of the tank and the soakaway (Section 4.5) will be dependent on which of these systems is chosen and thus on the volume of effluent which has to be absorbed.

Many designs for aqua privies are in use. Two are shown in Figures 6 and 17. An aqua privy for two families is shown in Figure 25. This Figure also illustrates how either a squatting slab and chute, or a pour flush pan, may be used. Figure 26 illustrates a large communal aqua privy suitable for an institution or camp.

In the case of the basic aqua privy (Figure 6), a volume of tank of approximately 1 m^3 is appropriate for a single family unit, or about 0.15 m^3 per person for privies serving larger groups of people. For a self-topping aqua privy, a tank volume of about 0.5 m^3 per person is required. Alternatively, if you know the volume of waste flow, you can design self-topping aqua privy tanks in precisely the same way as septic tanks, described below. The minimum volume should be 1 m^3.

The aqua privy tank must be watertight because if it leaks the water level will fall and so break the seal. The bottom of the overflow pipe should be carefully set 100-200 mm above the bottom of the chute; this provides the necessary seal because an aqua privy is always kept full to overflowing. To allow gases to escape from the tank, a vertical ventilator pipe is required; this is absolutely essential. When the tank is complete, and before building the rest of the latrine, test the tank for watertightness by filling it with water and leaving it for a few days.

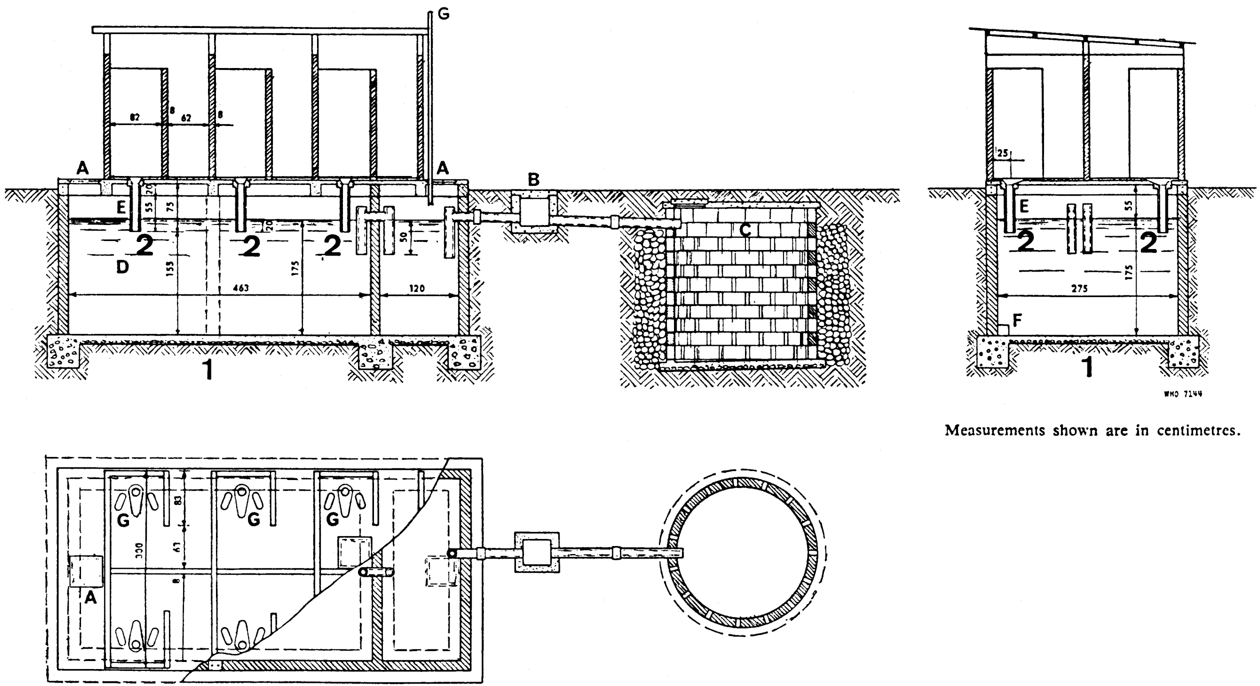
The design of the squatting plate has been described in Section 4.1. In general, the chute should have a diameter of at least 150 mm to prevent blocking, and should be fixed to the underside of the squatting plate. The outlet pipe from the tank should lead to a soakaway. Soakaways are described in Section 4.5. The tank of an aqua privy should be filled with water prior to use. The addition of a bucketful of sludge from another tank which is functioning satisfactorily will help to establish more quickly the normal digestive action in the tank. Sufficient water (at least 5 litres per user or about one or two bucketfuls) should be tipped into the tank every day. Disinfectants should not be added to the tank contents and neither should large quantities of detergent or strong alkali.

An aqua privy tank will slowly fill up with solid material, and should emptied when the sludge has reached one third of the tank depth. This can be ascertained by pushing a stick down into the tank's contents. Wrapping the stick in a white cloth makes the measurement more accurate. Emptying will be required every few years. If the tank is not emptied, the system will fail due to blocking of the outlet pipe. *Refuse of any kind should not be placed in an aqua privy.*

It is likely that scum floating on the surface will block the chute. It is necessary to clear the chute at least once a day by a wood or metal plunger on a long handle, which can be pushed down the chute. The plunger should be kept in a convenient place in a tray, to prevent it dripping on the floor of the latrine.

4·4 SEPTIC TANKS

Septic tanks are usually designed so that waste water takes at least 24 hours to pass through them. During this time heavier solids settle to the bottom forming a sludge, while lighter solids and grease float forming a thick scum (Figure 7). As in an aqua privy tank, the solids will undergo anaerobic decomposition which greatly reduces their volume. Septic tanks need to be cleaned out every 1-4 years to remove heavy accumulations of sludge. Too much accumulated sludge, together with heavy scum, will greatly reduce the volume of liquid in the tank, thus increasing the speed of flow and decreasing the time the waste water spends in the tank and preventing the tank from working properly. Excessive sludge build-up will also cause solids to be carried down the outlet pipe,



Measurements shown are in centimetres.

Reproduced by permission of the United Nations Relief and Works Agency for Palestine Refugees in the Near East.

Check list

1. Is the concrete tank of watertight construction ?

2. Do the drop pipes extend below water outlet level ?

A = Inspection manholes, 40 × 40 cm
B = Inspection box, 40 × 40 cm
C = Soakage pit or soakage trench
D = Capacity of tank : 22.3 m^3

E = Drop pipe 10.5 cm in diameter
F = Opening 15 × 15 cm in partition wall
G = Ventilator pipe

Fig. 26. An aqua privy installation suitable for an institution. (From Rajagopalan & Shiffman).

which will lead to the clogging of the soakaway. The effluent from the tank should be relatively clear and will normally have a greatly reduced concentration of organic material. However, it will be rich in faecal bacteria and other organisms and may contain any pathogens being excreted by the contributing population.

Septic tanks should have two compartments, as a better quality effluent is usually produced by tanks having more than one compartment. The first compartment should have twice the volume of the second. A typical two compartment tank is shown in Figure 7.

In order to permit effective sedimentation to take place, a liquid retention time of at least 1 day has been found necessary. Since, before desludging, the sludge and scum together may occupy up to two thirds of the tank volume, a septic tank should therefore be designed to hold three times the volume of waste flowing into it each day.

The total tank volume should not be less than 1.5 m^3. The depth of liquid in the tank at start-up should not be less than 1.2 m. Cleaning out the sludge from a septic tank will be made easier if the floor of the tank is sloping towards the inlet, thus causing most sludge to build up at one end of the tank. A little sludge should be left behind in the tank, to start off the process of digestion again. The operation of a septic tank will be severely hindered if strong disinfectants or alkalis, or large volumes or detergent are discharged into it.

In choosing a site for a septic tank, it is necessary to ensure that you can make satisfactory arrangements for disposing of the effluent, and that facilities exist for removal and disposal of the sludge.

Fresh sludge will contain a variety of disease-causing organisms, and should be handled carefully. When it has been thoroughly composted over several months, however, it can be used as agricultural fertilizer.

Septic tanks and soakaways should not be located too close to buildings and sources of water, or to trees whose growing roots may damage them. Table 3 gives guidelines for location in the form of minimum distances from various features.

4.5 SOAKAWAYS

A soakaway is a hole in the ground filled with stones, through which waste water can seep away into the surrounding soil. There are two kinds. A seepage pit, and a set of soakage trenches (also known as a drainfield or tile field).

Seepage pit

One form of soakaway is a seepage pit (Figure 27) which is dug into porous material in

Design of septic tanks

Total tank volume (m^3) = 3 × waste flow (m^3 per head per day) × population

Therefore: first compartment volume = 2 × waste flow × population
second compartment volume = 1 × waste flow × population

Desludging should be carried out when the tank is approximately one-third full of sludge. Sludge accumulation in the tropics may be estimated at 0.04 m^3 (1/25 m^3) per head per year. From this we can calculate that the desludging interval in years is given by:

25 × waste flow (m^3 per head per day), if the tank has a retention time of 3 days.

So, for a waste flow of 0.1 m^3 per head per day (100 litres per head per day), the interval would be 25 × 0.1 years; that is 2.5 years.

TABLE 3

Distance Requirements for Septic Tanks and Soakaways[1]

Minimum distance from	*Septic tanks* (m)	*Soakaway* (m)
Buildings	1.5	3
Property boundaries	1.5	1.5
Wells	30	30
Streams	7.5	30
Cuts or embankments	7.5	30
Pools	3	7.5
Water pipes	3	3
Paths	1.5	1.5
Large trees	3	3

[1] From Cotteral and Norris (1969)

places where the water table is not high. It is commonly 2-5 m deep, and 1-2.5 m in diameter. A seepage pit receiving the effluent from an aqua privy or septic tank should be as large as practicable, and never smaller than the tank itself. It is lined or filled with stones at least 50 mm in size, as shown in Figure 27. It will eventually fill up as the porosity of the surrounding soil decreases, and it may have to be replaced by digging a new pit every 6-10 years. Seepage pits should not be built within 30 m of a well or other water source, or uphill from one, and they are not appropriate to densely populated areas. They are also not appropriate where the natural water level in the ground is very high or where the soil is too fine for water to seep into it.

Soakage trench or drainfield

Soakage trenches are filled-in ditches containing open-jointed pipes of 100 mm diameter, laid on broken stone. They allow the effluent to be widely distributed through a large area of soil and they therefore minimise the risk of overloading in any one place. Normally several trenches are dug, each 15-30 m long, and connected together to make a drainfield.

A variety of misconceptions are widely held about soakage trenches and the following principles should be noted:

(i) The important seepage is through the sides of the trench and not the trench bottom which quickly becomes clogged. Therefore, trenches should be deep and narrow to maximise the side area which is

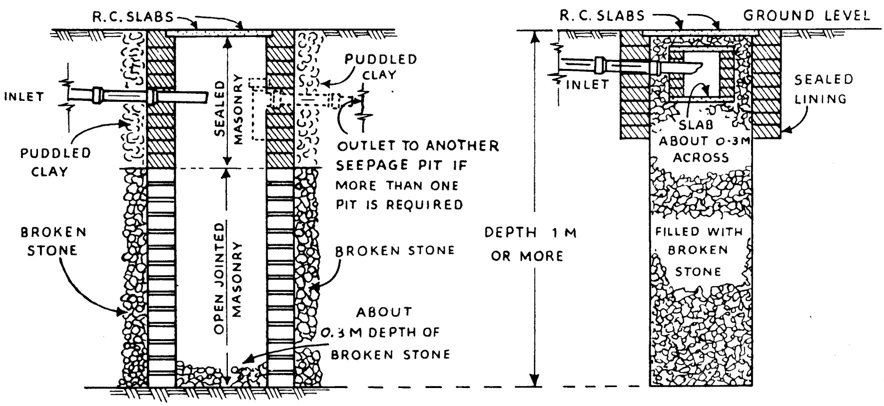


Fig. 27. Two kinds of seepage pit.

wetted. The length of trench required should be calculated on the basis of the available area of the trench sides, and *not*, as often recommended, on the trench bottom area.

(ii) Trenches should operate in series and not in parallel through distribution boxes. That is, they should be connected end to end, and the pipeline through them should not branch.

A typical arrangement is shown in Figure 28. The recommended values for the various design parameters are as follows (Cotteral and Norris, 1969):

Trench width	0.3-0.5 m
Gravel depth below pipe	0.6-1 m
Minimum trench spacing	2 m or twice trench depth (whichever is greater)
Area of land required for extension or replacement of clogged drainfield	100%

Knowing this it only remains to calculate the length of trench required.

The limiting factor in design, is the rate at which water can seep into the soil (the 'infiltration rate'), not in its natural condition, but after it has become partially clogged

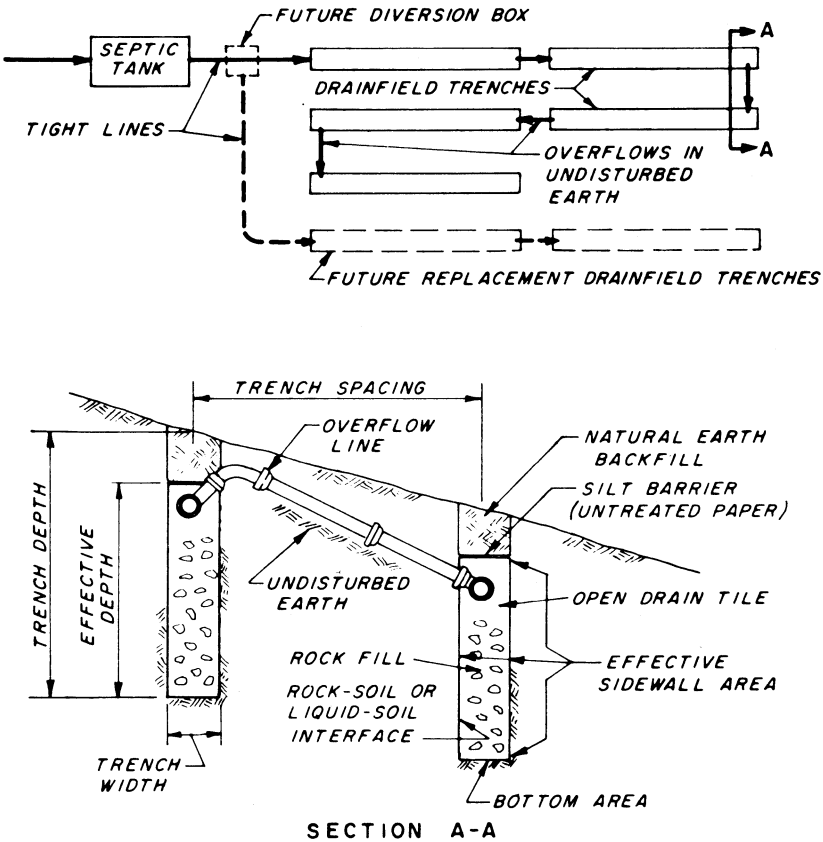


Fig. 28. A typical drainfield arrangement. (From Cotteral & Norris).

with sewage. This rate is roughly the same in most types of soil. A conservative and generally applicable infiltration rate of 10 litres per m^2 per day should be used.[1] The length of trench required may be calculated from the following formula:

$$\text{Length of trench (m)} = \frac{\text{number of users} \times \text{water use (litres/person/day)}}{\text{effective depth (m)} \times 10 \times 2}$$

The factor of 2 on the bottom line allows for the use of both sides of the trench. The effective depth is the depth from the water level to the bottom of the trench. Note that the bottom area of the trench is ignored.

This formula can be applied to most kinds of soil. But there are some soils into which water will soak only very slowly, so that soakage trenches cannot work. It is therefore recommended that infiltration tests be conducted to check on the soils of the area. A satisfactory test procedure is to drill at least three 150 mm diameter test holes, 0.5 m deep, across the proposed drainfield. These are filled with water and left overnight so that the soil becomes saturated. On the following day, they are filled to a depth of 0.3 m. After 30 and 90 minutes, the water levels are measured and the soil is considered to have a sufficient infiltration rate if the level in each hole has dropped by 15 mm in this period of 1 hour. However, you should *not* try to derive an infiltration rate from these tests, to use for the calculation of the trench length. The general figure of 10 litres per m^2 per day should be used in the manner described above.

Plain-ended tile pipes, or bell-and-spigot sewer pipes, may be used. Pipe lengths are generally 300-600 mm. Both types of pipe are laid so as to leave gaps of 6-12 mm between the pipe lengths to allow the effluent to leak out.

When plain-ended pipes are used, the upper half of the joint must be covered with a strip of roofing felt, tarred paper or broken pipe to prevent the entry of fine soils. The stones in the trench should be 20-50 mm size and should be covered by 300-500 mm of soil from the trench, over a protective layer of straw or untreated building paper.

The trench bottom and the pipes in each trench should be laid level. It may be helpful to lay the pipes along the top of a wooden plank, anchored on edge in the trench with stakes, in order to maintain a level grade. You can check that the plank lies level using a hose or plastic tube full of water, lying along the bottom of the trench and lifted up at each end to hold in the water. The plank should be level with the water at both ends. The tube is then removed and the plank left in when the trench is filled in.

The flow of waste water should not be split up by distribution boxes. The trenches should be connected end to end so that as each trench fills, the effluent overflows to the next one. Each trench should be level with, or below the ones before it.

The soil cover in the area should be a minimum of 1.5 m and the level of the seasonal high ground water table should be not less than 0.6 m below the trench bottom. Where water tables are high, or soil is highly impermeable, a soakaway mound may be tried. Figure 29 shows a possible mound arrangement, but the reader should be warned that this is not a fully tried and tested solution.

Evapotranspiration bed

Another version of the drainage field is the evapotranspiration bed. The effluent is distributed in open-joint pipes below the evapotranspiration bed which comprises a 200-500 mm depth of coarse sand and gravel underlying a 100 mm depth of topsoil planted with a fast-growing local grass. Grasses have high transpiration rates and the water content of the effluent is lost to the atmosphere by transpiration; the organic content fertilizes the grass, which is periodically cut. In order to protect the bed from floods during the rainy seasons, an earth bank should be constructed around the bed and suitable provision made for surface water drainage.

The size of evapotranspiration beds is calculated on the basis of the transpiration rate which is about 80 per cent of the rate of

[1] Laak *et al.* (1974) have shown that, for a wide range of soils, infiltration rates of effluent are between 10 and 30 litres per m^2 per day.

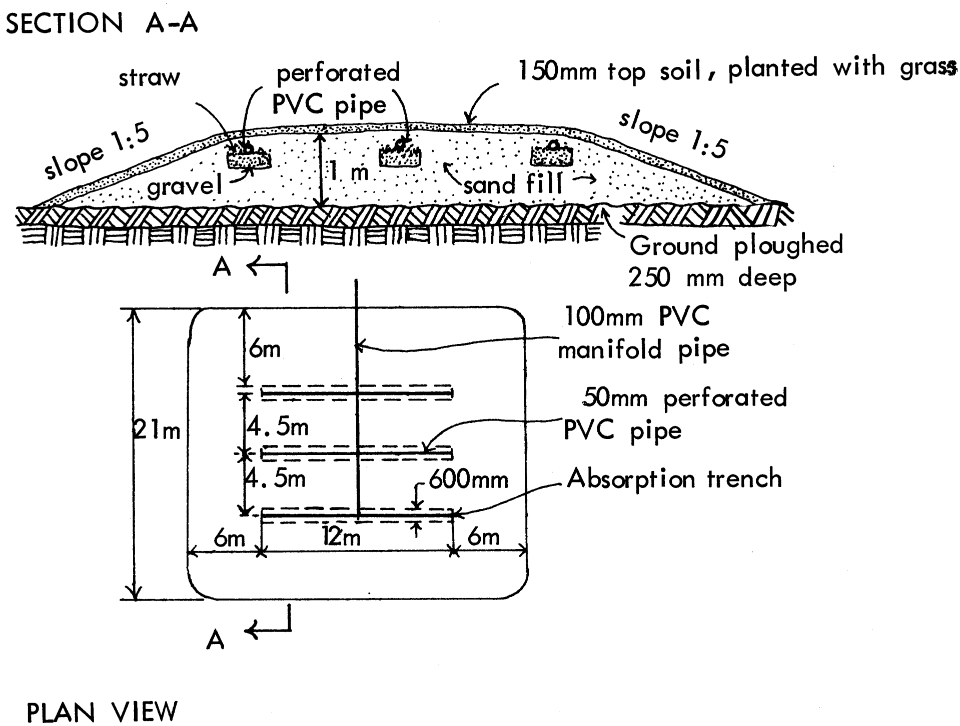


Fig. 29. A prototype design for a soakaway mound, for use in areas where the water table or rock is near the surface. (From Bouma et al).

evaporation from an exposed water surface, or on the basis of providing about 15 days' storage (during the rainy season) of the effluent in the sand layer, whichever gives the larger area.

Evapotranspiration beds need very conscientious management if they are to work well. It is usually preferable to combine them with soakage trenches as shown in Figure 30.

4.6 WASTE STABILIZATION PONDS

The advantages of waste stabilization ponds for sewage and nightsoil treatment in hot climates are mentioned in Section 2.5. Ponds are a natural and simple method of oxidising organic wastes and killing or removing micro-organisms. They are easy to maintain and operate and they require no machinery. Typical pond arrangements are shown in Figure 12. For further information see Mara (1976).

There are four main types of pond: anaerobic ponds, facultative ponds, maturation ponds and high-rate ponds. These are discussed in turn.

Anaerobic ponds

Anaerobic ponds are open septic tanks used to provide pretreatment of strong wastes. Anaerobic digestion and settlement takes place and a thick scum will develop on the surface. Common design practice is to allow a retention time of 1-5 days and a depth of 4 m. However, anaerobic ponds are appropriate for the treatment of large volumes of strong wastes and are not applicable to the systems mentioned in this booklet. In addition, if wastes have been through a septic tank or aqua privy then they have undergone an identical treatment process to that provided by an anaerobic pond. Anaerobic ponds, like septic tanks, need desludging every 3-5 years.

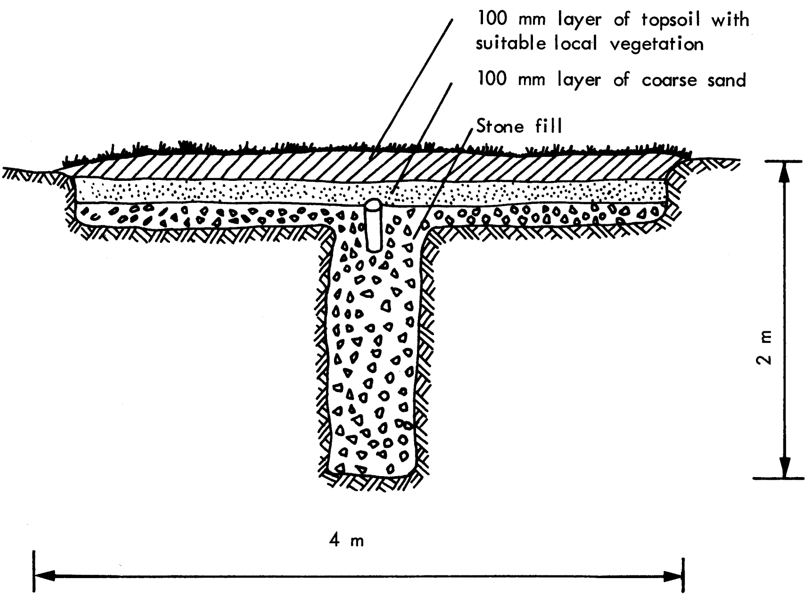


Fig. 30. A soakage trench combined with an evapotranspiration bed. (From Malan).

Design procedure for a facultative pond receiving nightsoil

(i) *Method*

Calculate the facultative pond area from:

$$A = \frac{22 \times P}{(2T - 12)}$$

where A = pond area (m^2)

P = population

T = the mean temperature of the coldest month (°C)

T can be found from meteorological records, available either from the government meteorological department or from a large airport.

(ii) *Example*

Supposing we have a pond serving a population of 200 in northern Nigeria, where T = 21 °C. Then:

$$A = \frac{22 \times 200}{(2 \times 21) - 12} = 147 \text{ m}^2$$

Facultative ponds
The facultative pond is the main work horse of a pond system and, in the absence of pre-treatment in anaerobic ponds, it is the pond into which the wastes flow first (see Figure 12). In the upper layers of the pond, oxidation of organic matter takes place and oxygen is provided by large communities of photosynthesising algae. At the bottom of the pond, sludge accumulates and anaerobic conditions prevail.

To design a pond it is simply necessary to calculate its area and its depth. Depth is chosen as 1.2 m, a compromise between too much anaerobicity in deeper ponds and the risk of emergent vegetation such as reeds in shallow ponds. The area can be calculated from a number of formulae. The method on page 46 is adequate in most cases.

Nightsoil may also be treated in a facultative pond by dumping it on a concrete ramp and sluicing down into the pond with a jet of water. Water lost by evaporation must be replaced to maintain a depth of 1.2 m., and pond area is calculated as described on page 44.

Maturation ponds
A facultative pond receiving sewerage must *always* be followed by two or more maturation ponds (see Figure 12). Maturation ponds are wholly aerobic and are responsible for the final improvement in chemical quality and for the reduction in the numbers of pathogenic bacteria and viruses. Although sophisticated design methods are available, a good rule of thumb is to choose 2 maturation ponds, each with a retention time of 7 days and a depth of 1-1.5 m. The retention time, rather than the surface area, is the major factor in this case. A 7 day retention time means that the volume of the pond must be at least 7 times the volume flowing through it each day.

Alternatively, three maturation ponds, each with a five day retention time and the same depth (i.e. having a similar total area) will provide a substantially better microbiological effluent quality.

High-rate ponds
These are still an experimental system for the rapid conversion of organic wastes into algae in shallow ponds. They are not yet an appropriate technology to be linked to the systems described in this booklet.

Design features
Stabilization ponds are quite large engineering structures, and should be carefully designed and built. A wrongly constructed pond can be a waste of effort and may even be dangerous, for instance if blocking of the outlet causes it to overflow and wash away the embankment. If possible, the advice of an engineer should be sought before building a pond system.

Ponds should be rectangular with a breadth to length ratio of 1 to 2 or 1 to 3. If excessive seepage losses (more than 10%) through the pond base are anticipated, the base should be lined with puddled clay, polythene sheeting, bitumen or other appropriate material. To line with puddled clay, place a 150 mm layer of moist clay on the floor of the pond, and persuade a herd of sheep or cattle to walk about in it until it has been completely remoulded by their footprints. However, this is not always necessary. A leaking floor in a facultative pond will soon seal up as sludge accumulates, although this will not occur to such an extent in maturation ponds.

The embankments for ponds are made of earth in the same way as small earth dams,[1] using suitably fine-grained soil such as a silty clay. The earth should be placed in 150 mm layers and well stamped down. The sides should slope at 1 in 2 or 1 in 3, and the top should be at least 1 m above the water level and 1.2 m wide. The sides of the embankments should be protected at the water level from erosion and vegetation growth. Concrete or stone paving or stabilized soil are appropriate.

If carted nightsoil is to be put into a facultative pond, a concrete or paved ramp is required down which to sluice it. If the pond is to receive water-borne wastes, the inlet pipe should be below the surface, to reduce the amount of scum. The inlet pipe should also stick out some distance into the middle of the

[1] Useful tips on the construction of earth dams are given in Appendix 7 of *Water supplies for rural areas and small communities*, by Wagner and Lanoix (1959).

Design procedure for facultative pond receiving sewage

(i) *Method*

The *depth* of the pond is set at 1.2 m if the sewage has come straight to the pond, and 1.5 m if it has already had some kind of previous treatment, for instance in a septic tank or aqua privy.

The rest of the calculation concerns the surface area.

Discover T – the mean temperature of the coldest month in °C.

Calculate K_T from $K_T = 0.30\,(1.05)^{(T-20)}$ or from Table 4.

Calculate the facultative lagoon area from:

$$A = \frac{Q(L_0 - 60)}{60\,K_T\,d}$$

where A = pond area (m^2)

Q = total flow of sewage (m^3/day)
= water use per person per day × population

d = depth

K_T = 'reaction rate constant' at temperature T, calculated above

L_0 = influent sewage strength (in mg/l of 5-day biological oxygen demand)

L_0 may be ascertained by asking a local engineer what strength of sewage he is encountering in your areas.
Alternatively, L_0 may be calculated by assuming a contribution of 40×10^3 mg of BOD per person per day. Thus:

$$L_0 = \frac{40 \times 10^3}{V} \text{ mg/l of BOD,}$$

where V = water use (litres/person/day)

If the sewage has passed through a septic tank or aqua privy before it reaches the pond, you may assume that its BOD has been halved.

(ii) *Example*

Suppose you are designing a pond to receive the septic tank effluent from a community of 200 people, using 100 litres of water per person per day.

$$L_0 = \frac{40 \times 10^3}{100} \times \frac{1}{2} = 200 \text{ mg/l}$$

$$Q = 100 \times 200 = 20{,}000 \text{ l/day} = 20 \text{ m}^3\text{/day}$$

If T = 21 °C (as in northern Nigeria),
then, $K_T = 0.30\,(1.05)^1 = 0.315$

Therefore A $= \frac{20\,(200 - 60)}{60 \times 0{\cdot}315 \times 1{\cdot}2}$ if we assume a depth of 1.2 m

$= 124 \text{ m}^2$

Therefore a facultative pond of area 124 m^2 is required. This should be followed by 2 or more maturation ponds.

TABLE 4
Values of K_T

$T(°C)$	K_T	$T(°C)$	K_T
1	0.119	14	0.224
2	0.125	15	0.235
3	0.131	16	0.247
4	0.137	17	0.259
5	0.144	18	0.272
6	0.152	19	0.286
7	0.159	20	0.300
8	0.167	21	0.315
9	0.175	22	0.331
10	0.184	23	0.347
11	0.193	24	0.364
12	0.203	25	0.383
13	0.213		

pond, firmly supported on columns, because sludge will tend to accumulate beneath it. The outlet from a pond, for instance for an interpond connection, should be at surface level. It should be surrounded by a scum guard, a barrier of boards at least 0.3 m deep which prevents scum from floating towards the outlet. Two types of interpond connection are shown in Figure 31.

Stabilization ponds should be surrounded by a secure fence or hedge to prevent children playing near them. Signs may also be put up to explain the purpose of the ponds, and so prevent their use for washing, etc.

Pond maintenance

Maintenance consists only of preventing vegetation growth, maintaining the fence, and removing any scum mats which may form. Vegetation will tend to grow down the banks and into the pond edges. It is essential to keep the banks and the area surrounding the ponds tidy and free of vegetation. If ponds become overgrown with vegetation, not only will their performance be hindered but breeding sites for snails and mosquitoes will be formed and these may promote the transmission of certain infectious diseases. For small pond systems, one or two labourers *under good supervision* are more than adequate to carry out routine maintenance tasks.

Facultative ponds will need desludging every 10-20 years, while maturation ponds should never need desludging.

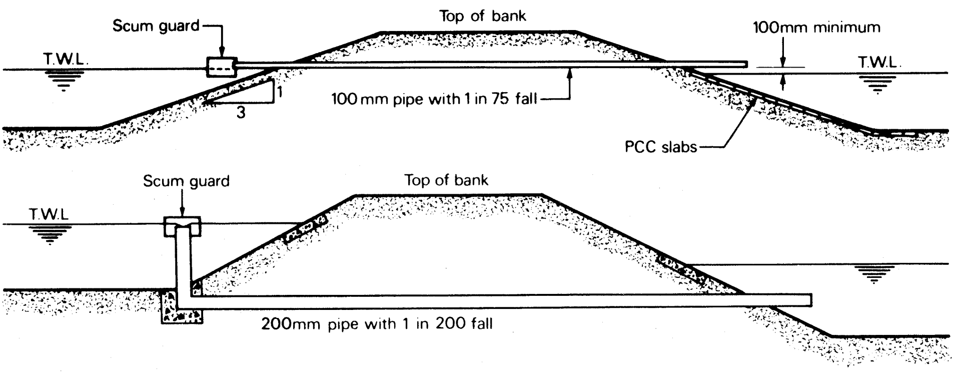
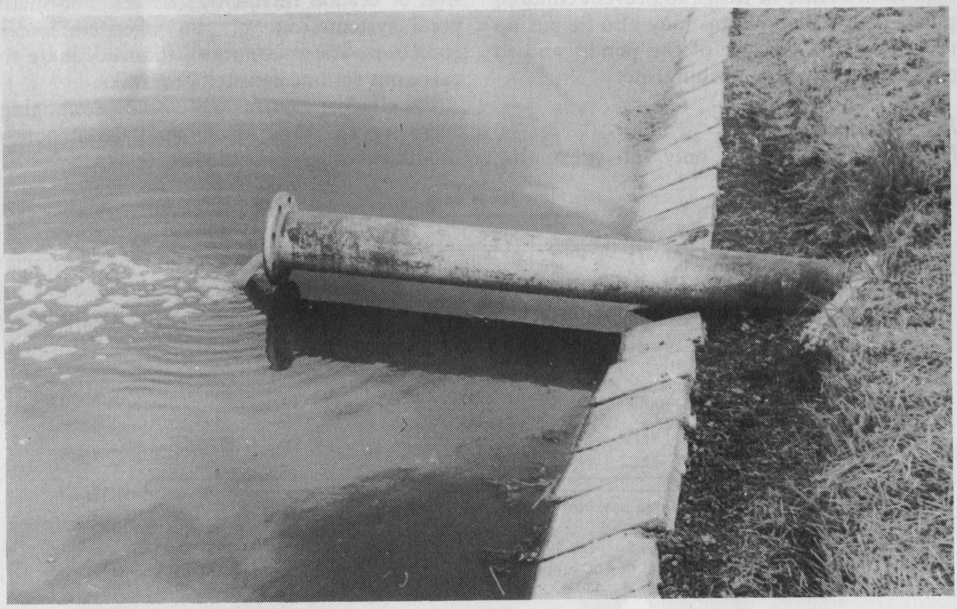


Fig. 31. Two examples of simple interpond connections. (From Mara). PCC: Pre-cast concrete.

Plate 10. Two waste stabilization ponds. The banks of pond 1 are not properly constructed and extensive colonization of the pond by vegetation is taking place. This will reduce the pond volume and allow snail and mosquito breeding near the shore. The pond is unfenced and there is nothing to prevent the cattle from drinking from, or wading in, the pond. Pond 2 is well constructed and the banks are clearly being kept clean. A simple inlet arrangement is also shown. (Photos: D. D. Mara).



CHAPTER 5 OTHER FACTORS

5.1 PUBLIC OR PRIVATE

Experience with public latrines of all kinds in all countries has often been unsatisfactory. The basic problem is that a public facility appears to belong to no-one individually and so there is very little commitment by individual users to keeping it clean and operating it properly. This is as true in Manchester as it is in Calcutta.

Public or communal latrines should only be considered for institutions (e.g. schools) or where paid employees can be made responsible for their continued cleaning and upkeep. The task of cleaning is made much easier if there is a tap in the block which may be used to hose down the floors and walls several times a day.

A compromise between public and private latrines, which is used in some parts of India, is to have a central latrine block serving 8 – 15 households, in which each household has an individual cubicle. The household keeps its cubicle locked and is responsible for its upkeep. Experience shows that each household will zealously guard its cubicle and keep it clean, but that maintenance to the overall system (e.g. blockage in the effluent pipe) will cause organisational problems.

Communal latrines often require lighting, or they will not be used after dark. Arrangements must be made beforehand to pay for this, because a community cannot raise money regularly by voluntary collections.

Another difficult question surrounding communal facilities is that of privacy. The requirements for privacy of the population must be understood and respected. Some possible layouts are shown in Figure 32.

Lastly, a communal latrine is necessarily a certain distance from each household, and this may be enough to deter users, particularly in wet weather. In some cases, it may be essential that each family have its own latrine, in or very close to the house. On the other hand, it may be worthwhile to construct communal latrines near the fields, where many agricultural communities spend most of their working day.

5.2 LOCATION AND SUPERSTRUCTURE

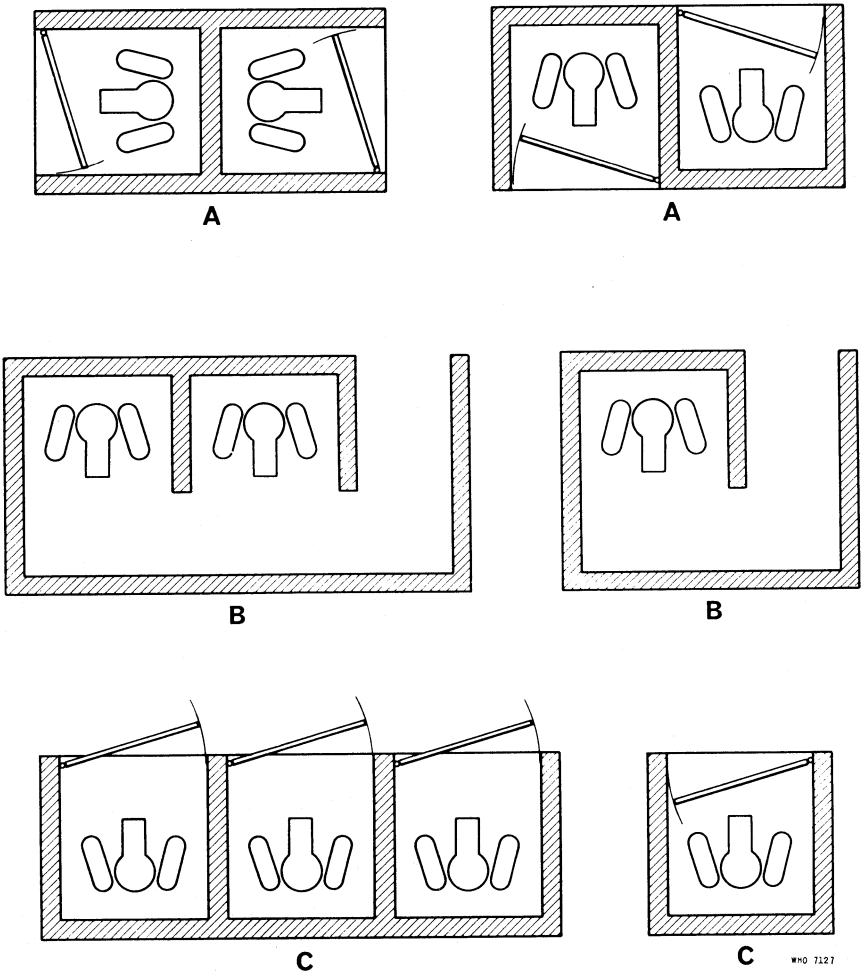
The prospective users of a latrine should always be consulted about its location. Not only the positioning of latrines, but also their direction of facing may be critical for them to gain acceptance. In some Muslim countries, for instance, latrines should not face Mecca.

The design of the superstructure (the hut or shelter housing the latrine) also requires sensitivity. In some cultures a roof may deter people, while in others if may be essential. Other features which may be necessary are: a shelf and hook for clothing, ablution jars and other possessions; handles to help with balance while squatting; and a long vertical handle on the cover for a squatting plate, so that it can be moved without bending down or soiling the hands (Figure 10).

Traditional building materials are normally suitable for the superstructure. A 300 mm space between the roof and walls will reduce the chances of the roof blowing off in high winds. The bottom 600 mm of the inside walls above the floor may be painted with bituminous paint, or treated in some other way to make them easier to clean.

5.3 INSECT AND ODOUR CONTROL

The best type of latrine is one in which the excreta are promptly flushed away into a closed tank or pit. In the other types of latrine, all openings leading to the excreta (including that in the seat) should be kept clean and closed when not in use. Unfortunately this rarely happens. Fly breeding in pit latrines may be checked by dusting the contents with borax, sodium fluosilicate or sodium arsenite, or by the use of oil-soaked sacking described in section 4.2. Odours may be reduced by regularly adding lime and ashes, which may also help with composting. In wet pits, the breeding of mosquitoes may be prevented by adding a cupful of kerosene to the pit each week. Disinfectants, however, should *not* be added.



A = These two layouts ensure complete separation of the sexes.

B = Semi-private installation. Snail-type entrance. Defaecation may take place in corridor passage when latrine floor is dirty.

C = Preferred types, ensuring complete privacy.

Fig. 32. Privy designs ensuring privacy and separation of the sexes. (From Wagner & Lanoix).

It has been found that the application of DDT, BHC, dieldrin or other residual insecticides to privies is sooner or later followed by a great increase in the housefly population because the chemical destroys the flies' competitors and predators and leaves unharmed the resistant flies. Pouring insecticides down privies is therefore not recommended, although insecticide on the walls and roof may help to keep away mosquitoes.

A 100 mm diameter vent pipe on a pit latrine may be sufficient to create a down-draught through the seat or hole and so reduce odour. But it should preferably be made 200 mm in diameter (Figure 16), so as to admit enough light to divert flies as well. Whatever the diameter, the top of the pipe should be covered with a fly-proof mesh, so that young flies emerging from the pit will not be able to escape through the pipe. Without this mesh, a vent pipe will not prevent flies from emerging and spreading disease – it will simply divert them from the latrine cubicle.

5.4 MAINTENANCE

By far the commonest cause of breakdown in latrines is the false, but all too general, impression that once installed they may be left to take care of themselves. Even the best excreta disposal facilities, whether they serve large communities or only single families, require some supervision and maintenance. Poorly-maintained latrines may be worse than none at all, especially if they lead people to associate latrines with filth.

All latrines must be kept clean; cisterns require periodic attention if they are to continue to flush correctly; septic tanks and aqua privies must be desludged at intervals; and the effluent disposal systems should be inspected regularly for blockages. A competent individual must be made responsible for this essential supervision.

In a septic tank or aqua privy the heavy insoluble particles sink to the floor of the tank and accumulate there as sludge. As sludge accumulates, the retention time in the tank falls and sedimentation becomes less and less efficient. Eventually, sludge begins to pass out of the tank in the effluent and it soon blocks the effluent disposal system (pits, trenches, etc.) so that the effluent can no longer seep away. The resulting pressure, if unrelieved, will continue backwards through the septic tank, along the sewers and into the privy until eventually the flushing water, instead of clearing the pan, may overflow and flood the floor of the privy.

Blockages of seepage pits and trenches usually reveal themselves by offensive fluid appearing on the surface of the ground above them. Blockages in sewers cause overflowing at the lowest manhole in the sewer line above the blockage.

Undue accumulation of sludge in a septic tank is usually due to neglect, but it may be aided by faulty design or the use of disinfectants. All septic tanks should be checked annually. It is possible to gauge the amount of sludge present by pushing a stick wrapped in a white cloth vertically downwards to the bottom of the tank. When the sludge nears one third of tank depth, it should be removed from the tank. This may be done by scooping it out, or by means of a sludge pump, but some should be left so that biological digestion may continue immediately. The tank should then be filled with water and put into service again.

GLOSSARY

Note: Names of components of excreta disposal systems are not included, as they are explained in the text.

aerobic	requiring air or oxygen.
alluvium	loose silt or clay deposited beside a river.
algae	microscopic water plants.
anaerobic	working without air or oxygen.
biogas	gas consisting mainly of methane produced by anaerobic digestion of organic waste.
composting	digestion without added water.
defaecation	the deposition of faeces.
desludging	removing accumulated sludge from septic tanks, aqua privies, etc.
digestion	the breaking down of organic waste by bacteria.
effluent	outflowing liquid.
excreta	in this Bulletin, 'excreta' refers to both faeces and urine.
facultative pond	a pond which is aerobic near the surface, and anaerobic down.
filariasis	a disease caused by a parasitic worm and transmitted by mosquitoes. Its symptoms include elephantiasis, a swelling of the legs.
hookworm	an intestinal parasite. At one stage of its life cycle (the larval stage) it emerges from the ground and can infect man by penetrating the sole of the foot.
maturation ponds	the final ponds in a series. They are entirely aerobic.
nightsoil	human excreta transported without flushing water.
organic	in this Bulletin, 'organic' means derived from living material.
pathogen	a pathogen or pathogenic organism is an organism which causes disease. Most pathogens are microscopic in size.
percolation	the soaking of liquids away into soil.
refuse	rubbish or garbage.
retention time	the period of time which wastes take to pass through a septic tank, stabilization pond, etc.
scum	solid material floating on the surface of a septic tank, pond, etc. Scum often comes together to form large floating masses, called 'scum mats'.
sewage	human wastes and waste water, flushed along a sewer pipe.
sewerage	a system of sewer pipes.
sludge	solid material which sinks to the bottom of septic tanks, ponds etc.
spoil	the soil which has been removed by digging a pit or trench.
superstructure	the hut or shelter built over the latrine.
transpiration	the movement of moisture from the soil into a plant's roots and up to evaporate from the leaves.
water table	the level in the ground at which water is found.

REFERENCES AND READING

ASSAR, M. (1971)
Guide to sanitation in natural disasters. World Health Organization: Geneva.

COTTERAL, J. A. and NORRIS, D. P. (1969)
Septic tank systems. *Journal of the Sanitary Engineering Division, Amer. Soc. Civil Engrs.*, **95**, 715-746.

FEACHEM, R., McGARRY, M. and MARA, D. (1977)
Water, wastes and health in hot climates. John Wiley and Sons: London.

FREEMAN, C. and PYLE, L. (1977)
Methane generation by anaerobic fermentation: an annotated bibliography. Intermediate Technology Development Group: London.

GOTAAS, H. B. (1956)
Composting. World Health Organization: Geneva.

LAAK, R., HEALEY, K. and HARDISTRY, D. (1974)
Rational basis for septic tank system design. *Ground Water*, **12**, 348-352.

MANN, H. T. (1976)
Sanitation without sewers – the aqua privy. Overseas Building Note No. 168; obtainable free from Overseas Division, Building Research Establishment, Garston, Watford, England.

MARA, D. D. (1976)
Sewage treatment in hot climates. John Wiley and Sons: London.

MARA, D. D. (1977)
Sewage treatment in hot countries. Overseas Building Note No. 17; obtainable free from Overseas Division, Building Research Establishment, Garston, Watford, England.

OKUN, D. A. and PONGHIS, G. (1975)
Community wastewater collection and disposal. World Health Organization: Geneva.

RAJAGOPALAN, S. and SHIFFMAN, M. A. (1974)
Guide to simple sanitary measures for the control of enteric diseases. World Health Organization: Geneva.

WAGNER, E. G. and LANOIX, J. P. (1958)
Excreta disposal for rural areas and small communities. World Health Organization: Geneva.

WAGNER, E. G. and LANOIX, J. P. (1959)
Water supply for rural areas and small communities. World Health Organization: Geneva.

NOTE: Most of these references are mainly of interest to engineers. The most convenient for further reading by the non-engineer are Assar (1971), Gotaas (1956), Mann (1976), Mara (1977) and Rajagopalan and Shiffman (1974). Wagner and Lanoix (1958) is a very thorough survey of the subject.

CONVERSION FACTORS

This Bulletin uses the metric system of units. Most of the measurements quoted in it do not need to be accurate to within less than about 10%, so that the following approximate rules for conversion may be used:

25 mm	:	1 inch
100 mm	:	4 inches
0.3 m = 300 mm	:	1 foot
1 m = 1000 mm	:	1 yard
1 m^2	:	1 square yard
1 ha	:	$2\frac{1}{2}$ acres
1 litre	:	2 pints
5 litres	:	1 gallon
0.1 m^3 = 100 litres	:	$3\frac{1}{2}$ cubic feet
0.5 m^3	:	18 cubic feet
1 m^3	:	35 cubic feet = 1.3 cubic yards

PUBLICATIONS OF THE ROSS INSTITUTE

The Preservation of Personal Health in Warm Climates ISBN 0 900995 01 7
(A handbook for those going to the tropics for the first time)

Ross Institute Bulletins:-

(1)	Insecticides. (Revised) July 1976.	ISBN 0 900995 02 5
(2)	Anti-malarial Drugs. (Reprinted) April 1975.	ISBN 0 900995 03 3
(3)	(Out of print)	
(4)	Tropical Ulcer. (Revised) August 1973.	ISBN 0 900995 04 1
(5)	The Housefly and its Control. (Reprinted) August 1974.	ISBN 0 900995 05 X
(6)	Schistosomiasis. (Reprinted) May 1974.	ISBN 0 900995 06 8
(7)	Malaria and its Control. (Reprinted) May 1974.	ISBN 0 900995 07 6
(8)	Small Excreta Disposal Systems. (Rewritten) January 1978.	ISBN 0 900995 08 4
(9)	The Inflammatory Diseases of the Bowel. (Reprinted) August 1975.	ISBN 0 900995 09 2
(10)	Small Water Supplies. (Rewritten) January 1978.	ISBN 0 900995 10 6
(11)	Anaemia in the Tropics. (Reprinted) June 1974.	ISBN 0 900995 11 4
(12)	Protein Calorie Malnutrition in Children. (Reprinted) June 1974.	ISBN 0 900995 12 2

These publications are revised from time to time and new and revised editions are issued as occasion warrants. They are available at printing cost plus postage on application to:-

The Secretary,
The Ross Institute,
London School of Hygiene & Tropical Medicine,
Keppel Street (Gower Street),
London, WC1E 7HT
Tel: 01-636 8636

ISBN 0 900995 08 4