Small Scale Sanitation

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SMALL SCALE SANITATION

Plate 1 A plastic chamber pot in use Children's faeces are generally more infectious than those of adults It is therefore especially important to make provision for children in any sanitation programme (Photo Isabelle de Zoysa)

THE ROSS INSTITUTE

Information and Advisory Service

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SMALL SCALE SANITATION

by

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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 the sanitary disposal of human excreta, and Dr. O J. S. Macdonald, the author of the first version of this Bulletin 35 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 widened beyond the planters and mine managers for whom it was originally planned, to include health inspectors, doctors, engineers and teachers. Drs. Cairncross and Feachem, from their extensive tropical experience, completely rewrote this Bulletin in 1978 to meet the needs of this wider audience, and their success in doing this has been clear from the demand for the Bulletin. Excreta disposal is no longer a forgotten element of public health activity, though practice still does not match up to intentions.

The subject has moved on in the last decade with new technological developments and new perceptions of how to achieve better excreta disposal for low income communities. Dr Cairncross has therefore again completely rewritten the text to provide a compact, readable and up-to-date account of small scale sanitation systems which will provide a practical guide for those who have to cope with excreta disposal problems in developing countries There is a great need for such an account and the author has filled it most lucidly and usefully.

David Bradley
Professor of Tropical Hygiene
Director of the Ross Institute

PREFACE

There is now a vast amount of published literature on small-scale sanitation, but the continued demand for this Bulletin indicates a need for a simple manual which brings together the main information the layman needs. It is written with a reader in mind who has at least secondary school education but not necessarily any technical training

This booklet is written, in the first instance, for those involved in sanitation programmes for low-income communities in developing countries. However, it should also be useful to anyone planning a small excreta disposal system in other parts of the world, whether it is to serve a remote farmhouse, a holiday cottage or a construction camp.

The various systems available for excreta disposal in small communities are described in simple terms, with an indication of how the most appropriate system can be chosen for particular circumstances Design formulae and dimensions 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.

For those seeking to study the subject further, a reference list is provided at the end of the Bulletin

ACKNOWLEDGEMENTS

The manuscript of this Bulletin was kindly reviewed by the following specialists in the field. They are busy people, but found time to offer many helpful comments which are gratefully acknowledged Any errors still remaining, however, are my own.

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Very special thanks are due to Professor Richard Feachem, who began my apprenticeship in sanitation and enabled me to prepare this new version of Bulletin No. 8, by twice recruiting me He has never failed to provide enthusiastic encouragement, and this Bulletin draws heavily on his work in the previous version Professor Mara's work was also an invaluable resource.

Eva Rickcord helped with several of the drawings, and Lynne Davies provided limitless secretarial expertise, cheerfulness and coffee.

Sandy Cairncross

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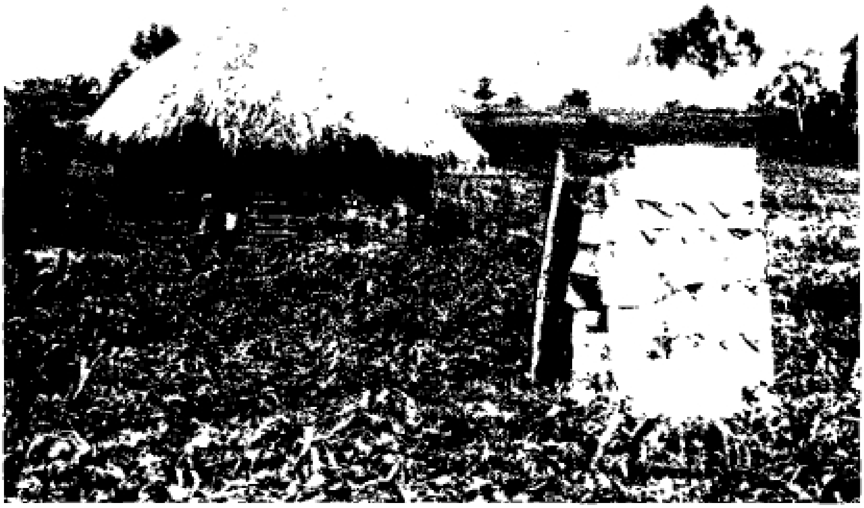


Plate 2 A simple pit latrine in rural Kenya A latrine of this sort is at least affordable, and may be quite acceptable for many years but tends to produce flies and, if it has a roof, to become smelly It may be upgraded to a VIP latrine as shown in Figure 4 (Photo R G Feachem)

Plate 3 The underside of concrete pour flush bowls and squatting slabs, made for installation onto pit latrines in Bangladesh. This can be done on a small scale without sophisticated equipment (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 health of all communities Indeed, the correct disposal of excreta is one of the most effective measures which any community can undertake to prevent disease 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, as well as those which are transmitted by insects such as cockroaches, flies and some mosquitoes, which may breed in excreta or polluted water. To understand the effects of excreta disposal on these diseases, we can divide them into categories, as described below. Table 1 lists the excreta-related diseases in each category.

I *Faeco-oral diseases (non-bacterial)* Many important diseases are transmitted by the faeco-oral route This means that the pathogen is present in the faeces of infected people, and can infect other people when they swallow it due to contamination of food, water, hands etc. Improvements in excreta disposal will have differing degrees of influence on the various faeco-oral diseases Some of these infections, caused by viruses, protozoa, and parasitic worms, can spread very easily from person to person whenever personal and domestic hygiene is not ideal Changes in excreta disposal methods are unlikely to have much effect on them unless accompanied by sweeping changes in personal cleanliness, requiring substantial improvements in water supply and housing, as well as major efforts in health education This group includes polio, hepatitis A and amoebic dysentery, among others

II *Faeco-oral diseases (bacterial)* For the faeco-oral diseases caused by bacteria, person-to-person transmission routes are important but so too are other routes with longer transmission cycles, such as the contamination of food, crops, or water sources with faecal material This group includes some of the most notorious diseases of poor hygiene, such as cholera, bacillary dysentery and typhoid fever Others, however, can also infect animals and birds, so that disposal of human excreta alone is not enough to control them

III *Soil-Transmitted helminths* This category contains several species of parasitic worm whose eggs are passed in faeces They are not immediately infective, but first require a period of development in favourable conditions, usually in moist soil Under suitable conditions, they can survive for months They then reach their next human host by being swallowed, for instance on contaminated vegetables, or by penetrating the soles of the feet Since the eggs are not immediately infective, personal cleanliness has little effect on their transmission, but any kind of latrine which helps to avoid faecal contamination of the floor, yard or fields will limit transmission However, if a latrine is poorly maintained and the floor becomes soiled, it can then become a focus for transmission Dirty latrines may transmit *more* disease than would occur if people were to defecate in widely scattered locations in the countryside

Small children tend to put all sorts of things in their mouths, so they are particularly likely to be infected with the worms whose eggs enter by mouth Their faeces are thus more likely to be infectious than the faeces of adults. The disposal of children's faeces is therefore essential for the control of these worms

IV *Beef and pork tapeworms* These tapeworms, excreted in the faeces, require a period in the body of an animal before re-infecting man when the meat is eaten without sufficient cooking One species of tapeworm is found in beef, the other in pork Any system which prevents untreated excreta or fresh sludge being eaten by pigs and cattle will control the transmission of these parasites

V *Water-based helminths* Various diseases are caused by worms which are passed in excreta and then develop in the body of an aquatic creature, usually a snail They then re-infect man through the skin or (depending on the species of worm) when insufficiently cooked fish, crabs, crayfish or aquatic vegetation are eaten Appropriate excreta disposal methods can help to control them by preventing untreated excreta from reaching water in which the aquatic hosts live However, most of these worms are also found in animal faeces so that measures restricted to human excreta can have only a partial effect Since one egg can multiply in the snail host to produce a thousand larvae, a low level of faecal contamination may still be enough to maintain transmission of the disease

Schistosomiasis (bilharzia) is the most widespread disease in this group and the only one where the worms infect man through the skin One kind of schistosomiasis, almost exclusively found in Africa, is passed in the urine The other two types, found

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

TABLE 1. Classification of Excreta-related Diseases

Category	Disease	Type of pathogen	Dominant transmission routes	Major control measures
I Faeco-oral (non-bacterial)	Poliomyelitis Hepatitis A Rotavirus diarrhoea Amoebic dysentery Giardiasis Balantidiasis Enterobiasis Hymenolepiasis	V V V P P P H H	Person-to-person contact Domestic contamination	Provision of toilets Domestic water supply Improved housing Health education
II Faeco-oral (bacterial)	Diarrhoeas and dysenteries *Campylobacter* enteritis Cholera *E coli* diarrhoea Salmonellosis Shigellosis Yersiniosis Enteric fevers Typhoid Paratyphoid	 B B B B B B B B	Person-to-person contact Domestic contamination Water contamination Crop contamination	Provision of toilets Domestic water supply Improved housing Excreta treatment prior to land application Health education
III Soil-transmitted helminths	Ascariasis (roundworm) Trichuriasis Hookworm Stongyloidiasis	H H H H	Yard contamination Ground contamination in communal defecation area Crop contamination	Provision of toilets with clean floors Excreta treatment prior to land application
IV Beef and pork tapeworms	Taeniasis	H	Yard contamination Field contamination Fodder contamination	Provision of toilets Excreta treatment prior to land application Cooking and meat inspection
V Water-based helminths	Schistosomiasis Clonorchiasis Diphyllobothriasis Fasciolopsiasis Paragonimiasis	H H H H H	Water contamination	Provision of toilets Excreta treatment prior to discharge Control of animals harbouring infection Cooking
VI Excreta-related	Filariasis (transmitted by *Culex quinquefasciatus* mosquitoes) Infections in Categories I-V especially I and II, which may be transmitted by flies and cockroaches	H M	Insects breed in various faecally contaminated sites	Identification and elimination of potential breeding sites Use of mosquito netting

B = Bacterium, H = Helminth, V = Virus, P = Protozoon, M = Miscellaneous in Africa, Asia and Latin America, are transmitted in faeces. Most of the other diseases in this group are found mainly in East and South East Asia.

VI *Excreta-related insect vectors.* These are of two main kinds. First, *Culex quinquefasciatus* mosquitoes, found throughout most of the world, breed in highly polluted water, for instance in septic tanks and flooded pit latrines, and transmit filariasis in some regions. This is the disease which causes irreversible swelling of the legs and other organs known as elephantiasis. It is an increasing problem in many tropical towns and cities. The second type of vector is the flies and cockroaches which breed wherever faeces are exposed. They can carry pathogenic organisms on their bodies and in their intestines. Their nuisance value is great, but their importance in spreading diseases depends on local conditions. Flies have been implicated in the spread of eye infections.

Latency and persistence

The pathogens causing the diseases in categories III, IV and V (Table 1) show a property known as latency. This means that they cannot infect a person immediately after they have been excreted, but must first undergo a period of development in soil, pigs, cows, or aquatic animals. Another important characteristic of each pathogen is persistence – how long it can survive in the environment. These factors are illustrated graphically in Figure 1. As might be expected, the latent and more persistent organisms have 'longer' transmission cycles, in the sense that they can spend longer and travel farther in the environment while passing from one victim to another. The efficacy of improved sanitation in controlling them depends on this cycle; a rough indication is given by the thickness of the 'sanitary barrier' in Figure 2.

Conclusions

The potential impact of sanitation improvements, and of improvements in personal hygiene, on the various categories of excreta-related disease, is summarized in Table 2. For most of these diseases, an improvement in excreta disposal is only one of several measures required for their control. It is essential that people of all ages use the improved toilets and keep them clean. The disposal of children's excreta is at least as important as that of adults. Studies in the past have often failed to detect beneficial effects from improved sanitation because, although latrines were built, they were not kept clean and were not used by children, or by adults when working in the fields.

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. For example, many Europeans have difficulty in adopting a squatting position for defecation and are reluctant to use water and hand for anal cleansing when they visit parts of Asia where this is the custom. Similarly, villagers who usually defecate in the countryside around their village (or townspeople accustomed to using vacant land) may be 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.

TABLE 2. **Potential for Control of Excreta-related Diseases by Improvements in Sanitation and Personal Hygiene**

Disease category from Table 1		*Impact of sanitation alone*	*Impact of personal hygiene alone*
I	Non-bacterial faeco-oral	Negligible	Great
II	Bacterial faeco-oral	Slight to moderate	Moderate
III	Soil-transmitted helminths	Great	Negligible
IV	Beef and pork tapeworms	Great	Negligible
V	Water-based helminths	Moderate	Negligible
VI	Insect vector	Slight to moderate	Negligible

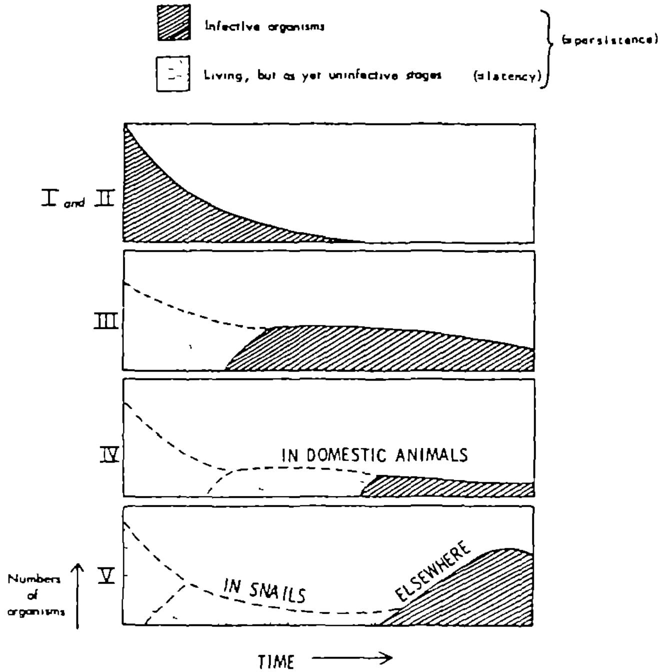


Fig 1 Latency and persistence in the environment for each category of excreta-related pathogen

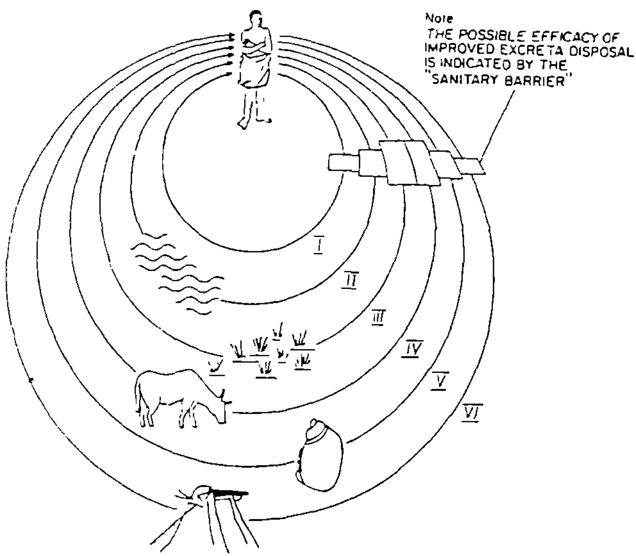


Fig 2 The length and dispersion of the transmission routes of the six categories of excreta-related disease, showing the possible efficacy of sanitation in controlling transmission

Types of sanitation programme
Broadly speaking, sanitation programmes in developing countries may be carried out in three contexts.

A *Site-and-service schemes*, where new housing and infrastructure are to be installed. This case poses least administrative problems as the excreta disposal facilities may be built directly by a centralised authority such as a municipality, the houses are arranged in a planned layout, and the cost of construction may be recovered from householders in the sale price or rent of the plots.

B. *Shanty town or slum improvement schemes*, where an important planning decision is the balance of responsibility between the sanitation agency (usually the municipal authority) and the householder. Where the householders are expected to build their own toilets in a 'self-build' scheme or to pay an installation or connection fee, it will not normally be possible to cover the whole community in the short term as some households will opt out of the scheme. If, therefore, it is desired to improve sanitation rapidly for *all* families in the area, the agency will have to finance the scheme and recover the cost by other means, such as local taxes or a surcharge on the water rates.

In improvement schemes, the existing housing layout and land tenure pattern often make the installation of infrastructure such as sewers or communal latrines more difficult However, an existing slum or shanty town is often a well-established community with strong local institutions such as residents' associations, and these may facilitate some form of community participation Sanitation improvements increase the value of urban land and housing This may lead land-owners to charge higher rents, or forcibly remove poor tenants or squatters so as to rent or sell the land to richer families. Tenants and squatters will require some guarantee of security of tenure if they are to invest time or money in sanitation improvements.

A sanitation programme in this context will usually benefit from inclusion in a general programme for infrastructural upgrading, including roads, drainage and water supply, as this can more easily guarantee the necessary funding, land, water, and street alignment. Recovery from the householders of the money invested can also be achieved more easily in this context. Moreover, a wider upgrading programme is more likely to improve general hygiene and provide the necessary conditions for a change in excreta disposal practices, thus helping to achieve the health benefits which are hoped for from the programme

C. *Rural sanitation programmes* generally rely heavily on householders to build their own latrines, although they may be given some assistance, for example by the sale or distribution of floor slabs for pit latrines In rural programmes, the technical and administrative problems are small when compared with the great difficulty of encouraging the rural population to use and maintain the facilities In some countries there have been programmes to provide pit latrines in rural areas for at least seventy years. In general these have been unsuccessful, not because of a problem of construction but because the latrines, once built, were either not used or not maintained.

There are no simple solutions to this problem but from previous experience a number of guiding principles have emerged, which should be borne in mind by anyone involved in a rural latrine programme These may be summarized as follows.

1 Excreta disposal is a sensitive matter about which people have strong cultural preferences. Therefore, it is imperative to achieve the maximum involvement of the community in the design and implementation of any sanitation programme Solutions imposed from outside are unlikely to succeed Often, a modification to an existing practice or type of latrine

may be much easier to implement then a completely new sanitation technology

2. People require a reason or a motivation for using a new kind of latrine. In general, the desire for improved health is not the most likely source of motivation because the connection between latrine usage and health is often not perceived. An important motive is the desire for privacy In some circumstances, as in parts of Asia, the re-use of excreta in agriculture or fish-farming may also provide an economic incentive.
3. Any type of latrine needs good maintenance and will become fouled and offensive without it. If this is allowed to happen the latrine will either not be used or will become a major health hazard in itself.

'Exotic' and 'mundane' factors

The social aspects of sanitation are often seen in terms of strange and exotic beliefs in the community Some of these may exist, but more often the problems are simple and mundane difficulties which can be resolved largely by common sense and a knowledge of how the users live.

An example of an exotic factor found in various countries is that sons-in-law and mothers-in-law may avoid using the same latrine Where this happens, it may be easier to provide a second latrine for each household than to try to persuade them to change their customs. Another such factor is the taboo in some Muslim countries against defecating while facing Mecca The implications for latrine construction are obvious

The mundane factors which are sometimes not considered are the cost, convenience, and organisation necessary for the users if they are to make correct use of the sanitation system

The Cost of the new toilet may compete as a priority with extra living space or other home improvements, and some systems may require new payments, such as water bills, for their operation or their upkeep A sanitation system may appear to be gaining quite wide acceptance without reaching the poorest people, who most need it In the case of self-build schemes, an important factor is the cost and difficulty of obtaining building materials and prefabricated components such as vent pipes or squatting pans. Cost is further discussed in Section 3 2.

Convenience is a rather wide concept, but includes such factors as how much time is saved, how the location of facilities influences their use, and whether facilities are equally convenient to all household members and at night It is particularly important that children should have easy access to toilets and that there should be no fear, justified or not, associated with their using them.

Organisation is important when the continued functioning of the latrines requires the establishment on a permanent basis of adequate municipal capacity to maintain and repair latrines, to empty pits, clean out septic tanks and so on It becomes critical when communal toilets are to be used. In general, if facilities must be shared between households, problems will arise unless someone is appointed and adequately rewarded to look after them and keep them clean.

The local authority cannot abdicate its responsibility to ensure that communal latrines are operated and maintained satisfactorily If it is considered essential to recover the operating and maintenance costs directly from the users, it will be more reliable to charge for admission This has been tried successfully in parts of India, where the small admission fee also covers the cost of soap for washing. However, even a small charge will discourage some people, especially children, from using the latrines

The likely effects of the various social factors on a sanitation programme may be foreseen to some extent by studying existing excreta disposal practices Still more valuable is a study of similar communities where new sanitation technology has been introduced and accepted – or rejected. How many users are contributing to maintenance, and how much? What happens when pits or septic tanks need to be emptied? Observation of how facilities are being used (or misused) will suggest some design modifications, and others will be found to have been carried out already by individual householders. Local staff and community representatives can point to problems which arose during construction, such as shortages of materials, over-rigorous building regulations, insufficient supervision of construction, and so on.

The extension system

It is the function of an extension system to discover and deal with problems of implementation which have not been resolved at the planning stage An extension system is particularly important where self-building is involved, and should promote the construction, correct use and maintenance of improved toilets through health education and other means, while at the same time collecting feedback from the community about difficulties and design improvements

Community-level primary health care workers are suitable promoters for a sanitation programme, provided they are given the necessary support through visual aid materials, radio campaigns, and so on. Other means may include technical assistance, demonstration models, the installation of latrines of the appropriate type in schools, clinics and community centres, and the advertising of credit arrangements and other forms of help to the householders

The extension system will itself cost money and require staff, which must be provided for, in good time; 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.

Children and sanitation

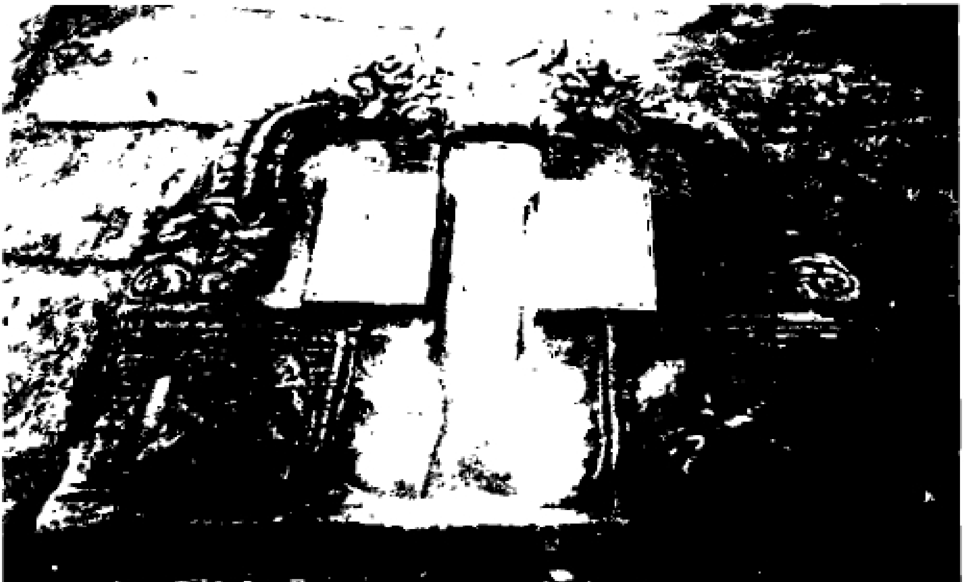
It has been mentioned that children's faeces are more likely to contain disease pathogens than those of adults, so the disposal of children's faeces is especially important. One way to start children in the habit of sanitary excreta disposal is to use a chamber pot, to be emptied into the latrine These can be manufactured cheaply of plastic (see Plate 1) or made locally by a village potter.

Another solution is a child's pit latrine near the house, with a specially made floor slab and a smaller than usual drop hole. The pit can be very small if only one or two small children will use it, and no superstructure is necessary.

A third possibility is to use a special cover piece over the seat, drop-hole or squatting pan of an adult latrine, to make it smaller and so more convenient and less frightening for a child to use

Where communal or public latrines are used, it may be appropriate to build children's latrines beside them. This has been successfully tried in Madras, India, where the children's latrines are divided into individual roofless compartments by a small wall, low enough for the mother, standing on the other side, to bend down and assist her child

Plate 4 A VIP latrine built of local materials in rural Zimbabwe, which has been in use for many years Since it was built, it has become apparent that it is not necessary to paint the vent pipe black (Photo D D Mara)



Plaze ~ This pour-flush squatting plate is 2000 years old and was made for a

Plate 5 This pour-flush squatting plate is 2000 years old and was made for a king! It is in the ruins of Anuradapura, Sri Lanka (Photo J Knapp)

CHAPTER 2 SANITATION SYSTEMS

2.1 TYPES OF SYSTEM

The conventional cistern-flush toilet with sewerage is probably the type of excreta disposal system most familiar to the reader, but it is by no means the only one available or even the most appropriate for low-income communities or for many rural environments It uses a great deal of water to move the excreta along the sewer pipes, but other systems which use much less water or none at all can be equally hygienic. Even the pit latrine can be designed in such a way as to be free of flies and smells, and to be clean, safe and agreeable to use

The first distinction between types of system, then, is between *'wet'* and *'dry'*. In wet systems, water is used to flush the excreta away and some of the flushing water remains in a U-pipe to seal off the excreta from the user The flushing water may be poured by hand or discharged from a tank or cistern In the dry systems, the excreta drop through a hole into a pit, vault or other receptacle This may be designed in such a way as to control flies and smells.

Some systems, both 'wet' and 'dry' involve *on-site* disposal of the excreta, or at least of the liquid component, in the nearby ground Others require a system of pipes or sewers to drain the excreta away, or some form of transport such as a cart or truck to remove them periodically, for *off-site* disposal The main types in each category are listed in Table 3, and illustrated in Figure 3 The following sections describe them in outline and suggest how to choose the most suitable system

2.2 PIT LATRINES

Pit latrines are the commonest, simplest and cheapest sanitation system. The excreta are collected in a hole in the ground, generally located directly beneath a squatting slab or seat Liquids soak into the ground, and the solids accumulate in the pit When the pit is two-thirds full, it is filled in with earth and a new pit is dug nearby.

Pit latrines are almost universally applicable in rural areas and can often be built with materials available locally. They are also widely used in urban areas.

VIP latrines

The conventional pit latrine has two main disadvantages; it tends to be smelly, particularly if it has a superstructure with a roof over it, and it can produce hundreds of flies a day. These flies, having bred in the excreta in the pit, may land on food or utensils and spread disease These two problems are very much reduced in ventilated improved pit (VIP) latrines (Figure 4). Wind passing over the top of the vent pipe causes the air inside to rise and escape to the atmosphere, so creating a downdraught of air through the drop hole or seat This circulation of air removes the smells coming from the excreta in the pit

TABLE 3 **Types of sanitation system**

	On site disposal	Off-site disposal
Dry	1 Pit or borehole latrine 2 Ventilated Improved Pit (VIP) latrine 3 Twin pit latrine 4 (Compost toilet)	8. (Bucket latrine) 9. (Vault toilet)
Wet	5 Pour-flush toilet 6. Septic tank and soakaway 7. (Aqua privy)	10. Sewerage. – small bore – (conventional)

Note Systems listed in brackets are not recommended for low-income communities in the tropics except in special circumstances

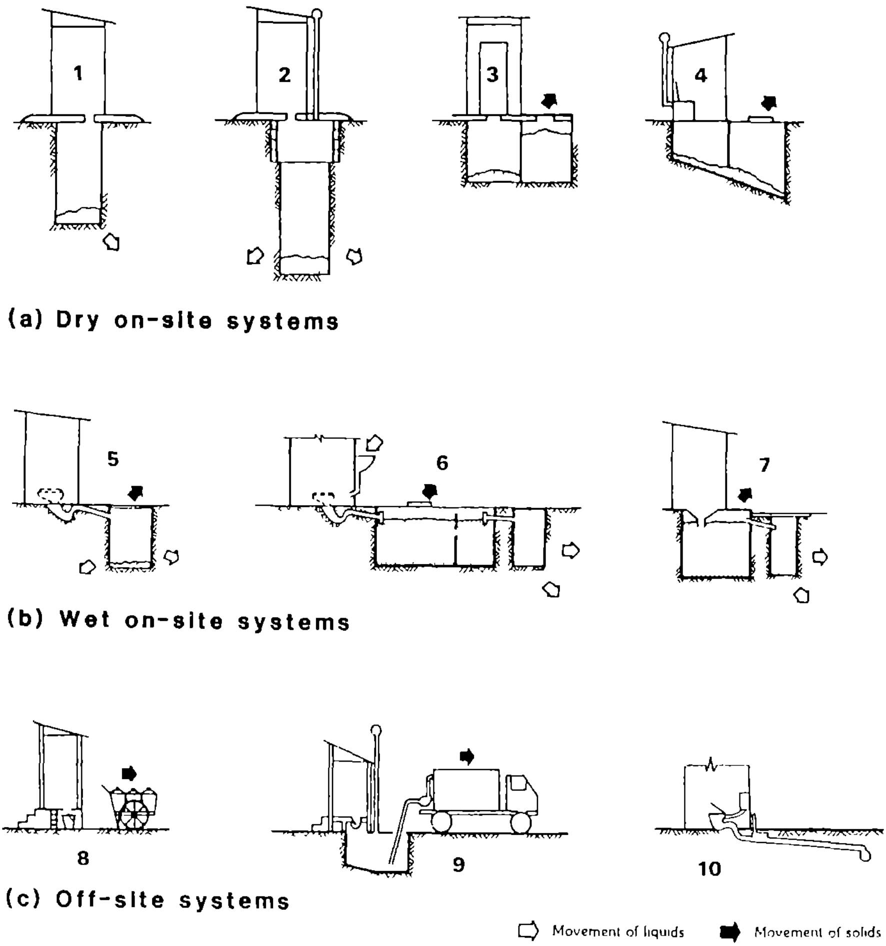


Fig 3 Common sanitation systems

1 Pit latrine
2 VIP latrine
3 Twin pit latrine
4 Compost toilet
5 Pour-flush toilet
6 Septic tank and soakaway
7 Aqua privy
8 Bucket latrine
9 Vault toilet
10 Sewerage

(After World Bank, 1980)

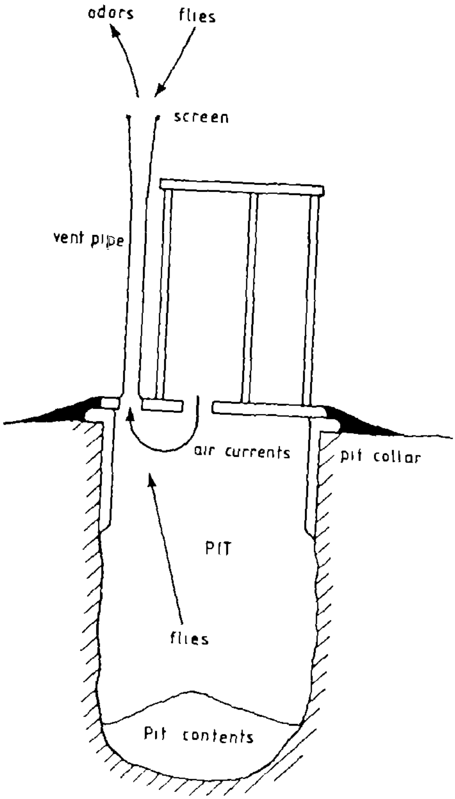


Fig 4 VIP latrines
(a) Functioning of a VIP latrine

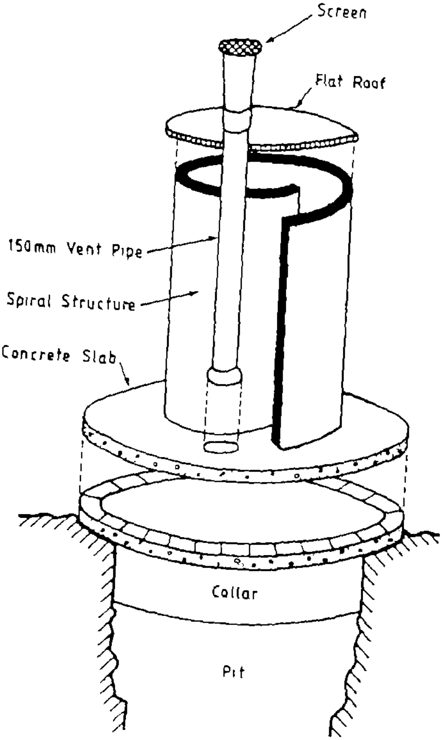


Fig 4b Diagram of a VIP latrine with a spiral ferrocement superstructure

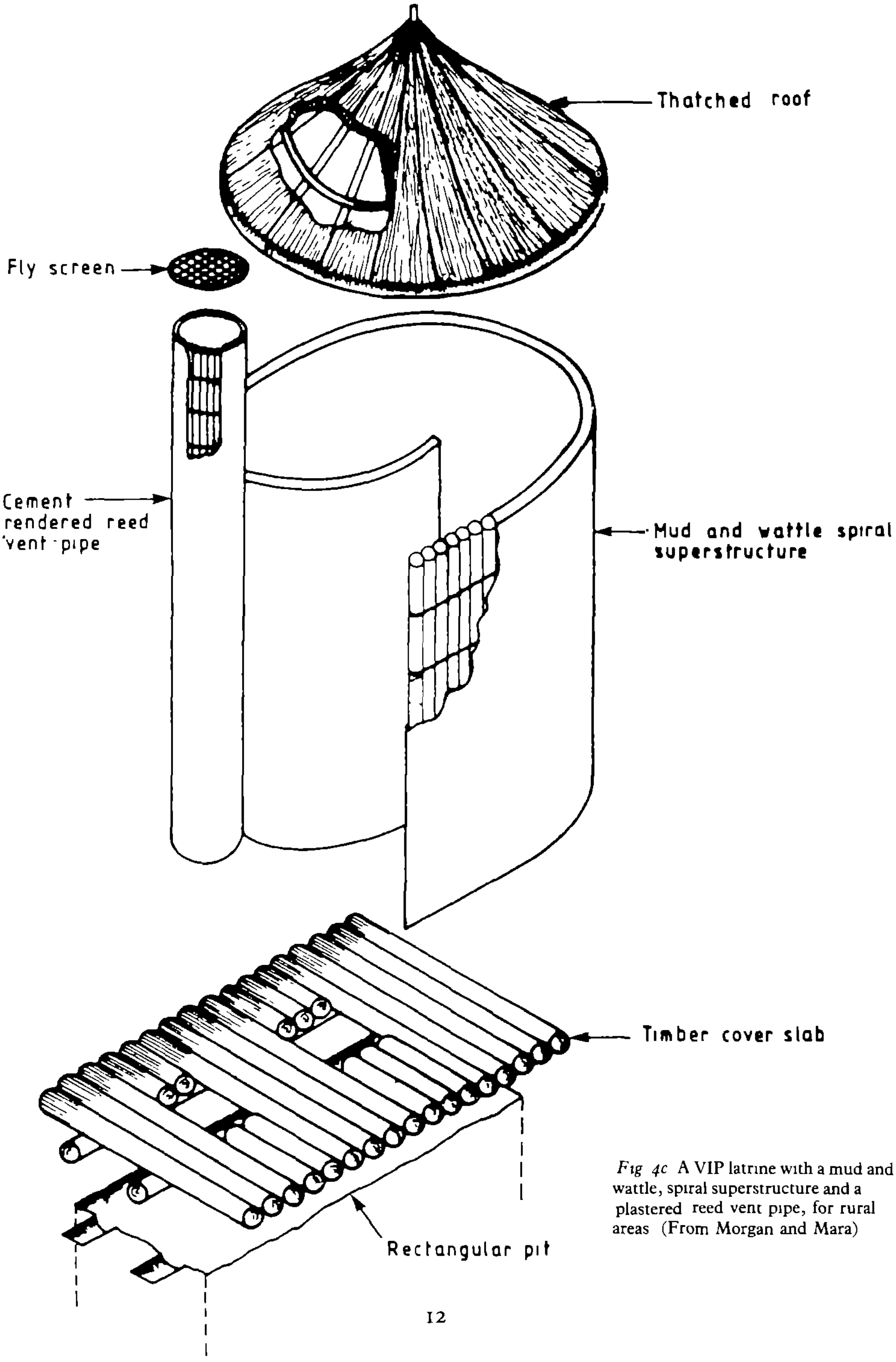


Fig 4c A VIP latrine with a mud and wattle, spiral superstructure and a plastered reed vent pipe, for rural areas (From Morgan and Mara)

The vent pipe also controls flies Female flies, searching for a place to lay their eggs, are attracted by the smell from the vent pipe but are prevented from flying down the pipe by the fly screen at its top (Figure 4). Nevertheless, a few flies may enter the pit by the drop hole and lay their eggs When new adult flies emerge they instinctively fly towards the light, however, if the latrine is suitably dark inside the brightest light they see is that at the top of the vent pipe. If the vent pipe has a suitable fly screen at its top, the new flies cannot escape and they eventually fall down and die

Unfortunately, the system is not so effective against the mosquitoes which may breed in flooded pits where there is a high water table (Section 4 3).

Twin pit latrines

Sometimes there is not enough space to dig and re-dig sufficient pits for the whole community, moving each latrine to a new place whenever it is full. In such cases, each latrine can be built with two pits, each large enough to last for two years before filling up. Each pit must then have a lining of brick or concrete, although the lining should have holes in it to allow liquids to flow through it into the ground. Only one pit is used at a time When the first pit is nearly full, it is sealed, usually by covering the excreta with earth, and the other pit is used. After a year, the excreta in the first pit can be handled safely, as any pathogens in it will have died. The first pit can be emptied and the contents, now transformed into unobjectionable humus, can be disposed of or used on fields or gardens as a fertilizer and soil conditioner

The cost of adding vent pipes is usually small compared with the cost of the pits, so that it is a good idea to build twin pit latrines as VIP latrines

2.3 POUR-FLUSH TOILETS

A further improvement to the pit latrine is to fit a water seal, which is a U-pipe filled with water, below the seat or squatting pan (Figure 5), and which completely prevents the passage of flies and odours. If the pan is well designed and holds only 1 5 litres of water it can be flushed by hand. The small amounts of water used are sufficient to move the excreta a few metres down a pipe, so that the pit need not be directly under the superstructure. The pit is usually offset to one side, to make it more accessible for emptying and improve the stability of the foundations. Two pits are often used, in the same way as a twin pit latrine, so that the toilet does not have to be moved when a pit fills up

The advantage of pour-flush systems over pit latrines is the complete elimination of odour, flies and mosquitoes by the water seal They can be located inside the house if desired, and not necessarily on the ground floor.

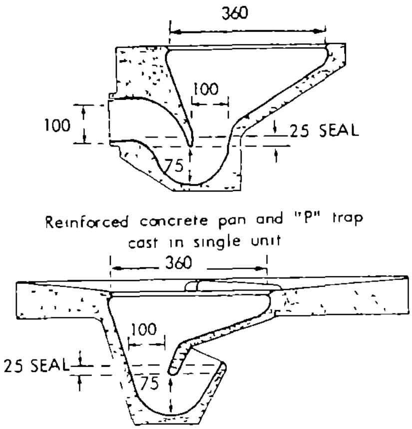


Fig 5 Alternative types of pour-flush latrine pan The lower version is designed to replace the floor slab of a pit latrine, so as to give it a water seal

Pour-flush toilets are common in the Indian subcontinent and the Far East and are becoming widespread in Latin America. They are particularly suitable wherever water is used for anal cleansing Since flushing is done manually, they do not require a multiple-tap in-house level of water supply, they are best used together with a yard-tap level of water supply, but the flushing water can also be carried from a public standpipe if it is not too far away

Sewered pour-flush systems

If the soil conditions do not allow the liquids (urine and flushing water) to soak into the ground from the pit, a pour-flush toilet may still be feasible; but in this case it should discharge into a septic tank and from there to a sewer A small bore sewer can then be used Septic tanks and sewers are discussed below.

2.4 SEPTIC TANKS

A septic tank is a watertight settling tank, usually divided into two compartments, to which wastes are carried by water flushing down a short sewer A septic tank does not dispose of wastes, it only helps to separate the solid matter from the liquid. Some of the solids float on the surface, where they are known as scum, while others sink to the bottom where they are broken down by bacteria to form a deposit called sludge. The liquid effluent flowing out of the tank remains to be disposed of, normally by soaking into the ground from a soakaway, and the sludge accumulating in the tank must be removed every few years

A soakaway is usually a pit or trench filled with stones, broken bricks or other rubble. It allows the waste water to filter through the sides into the ground and disperse. Sometimes it is in the form of a pit lined with open-jointed masonry The size of a soakaway, and the area of land it requires, will be determined mainly by the volume of waste water produced and the local soil conditions. The siting of a soakaway must be carefully chosen to avoid the pollution of water supplies (Section 3 5).

Septic tanks can receive waste household washing water or sullage as well as the wastes from toilets, but then a larger amount of space is required for the soakaway system to cope with the greater quantities of water involved. This means that in relatively high density areas (more than about 100 persons/hectare) there may not be sufficient space for adequate soakaways.

In that case the effluent can be discharged into a small-bore sewer (see below) or a covered stormwater drain. However, effluent from a septic tank is just as much a health hazard as raw sewage, and should not be allowed to flow into open drains.

2.5 SEWERAGE

When the wastes (sewage) flowing in the pipes of a sewerage system have not passed through a septic tank, the pipes must have a minimum downward slope to ensure the flow is strong enough to move the solids. Unless the lie of the land is unusually favourable, this means that pumping stations are required and the sewers often have to be laid in very deep trenches The design of sewerage systems is complex, but a relatively routine exercise for a qualified sanitary engineer, and is described in many standard textbooks on the subject

Conventional sewerage is the system found in most towns in Europe and North America and in certain high-income communities elsewhere. It is very expensive, although recent research into 'shallow sewerage' has suggested ways to cut costs considerably (see Section 4.6). It also requires large quantities of water to move the solid wastes along the pipes, so that a cistern which discharges about 10 litres with each flush is normally necessary If the water supply is not reliable the sewers are likely to become blocked when not enough water is available for flushing. Moreover, mixing the waste with large amounts of water may make it harder to treat and to dispose of in the environment, particularly in areas where there are no large constantly-flowing rivers into which to discharge it

Small bore sewerage

This cheaper form of sewerage is possible where only liquid wastes are to be transported, as in the case of effluent from a septic tank. Because the large solids have been removed, the pipes can be as small as 75 mm in diameter and a continuous downward gradient is not required, so that this system can cost less than conventional sewerage. It is most suitable when pour-flush toilets are used but on-site disposal of the effluent is not possible, and when existing septic tank systems have failed due to overloading of the soakaways.

2.6 OTHER SYSTEMS

The following systems are not generally recommended, but they are described briefly as they are already in widespread use.

Bucket latrines

The bucket latrine is one of the oldest and generally least hygienic systems 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. The bucket is positioned adjacent to an outside wall and is accessible from the street or lane A collector will call regularly – preferably every day but more typically once or twice a week – and will empty the bucket When emptying the bucket into the barrow or cart, some of the excreta are often spilt so that the area becomes heavily contaminated The same occurs at the depot where the contents of the carts are emptied for transportation in trucks or for treatment or agriculture.

Ideally, as each full bucket is removed a new disinfected bucket should be put in its place Full buckets should be sealed with a lid for transport before being emptied. The practice of emptying the bucket and immediately returning it to its position 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 a particular day 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 only work well under situations of tight institutional control, where all operations are carefully supervised. It should be regarded as a temporary measure suitable for camps, for instance, while more permanent solutions are being constructed even then, pit latrines will often be more appropriate.

Vaults

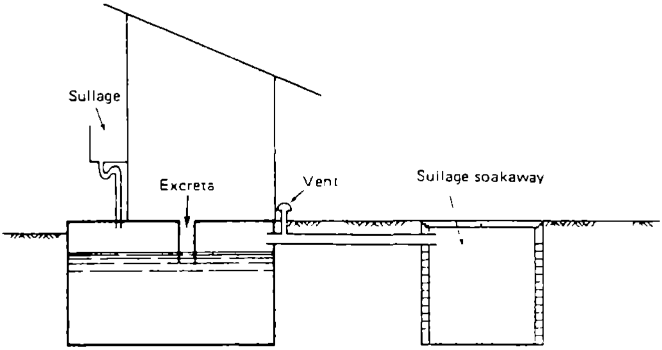
Many households in the Far East store their excreta, plus the small amounts of water used for pour flushing and anal cleansing, in sealed tanks or vaults under or beside the house. These vaults are emptied about once every two weeks by a vacuum truck This system has relatively high operating costs but 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.

Aqua-privies

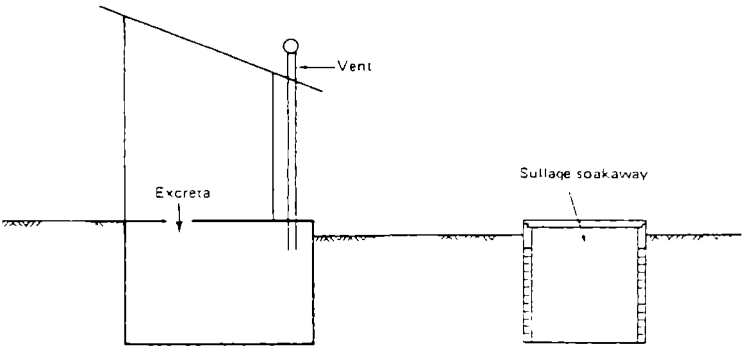
An aqua-privy is essentially a septic tank located directly underneath a latrine. The excreta fall down a 100-150 mm diameter vertical drop-pipe extending some 100 mm below the liquid level of the tank, thus forming a crude water seal. A couple of buckets of water should be poured down it each day to clear scum (in which flies may breed) from the bottom of the drop pipe and to maintain the water seal, which is necessary to prevent mosquito and odour nuisance.

In practice, the water level tends to fall due to a low inflow or to leaks in the tank, so that the water seal is not maintained. Discharging sullage into the tank (by connecting the waste pipes from basins, showers etc.) has not proved satisfactory When the flow of sullage is relatively large and especially in high-density areas, soakaways cannot dispose of the effluent, so that it has to be discharged into a small-bore sewer. In that case a second compartment is required to settle out the solid matter.

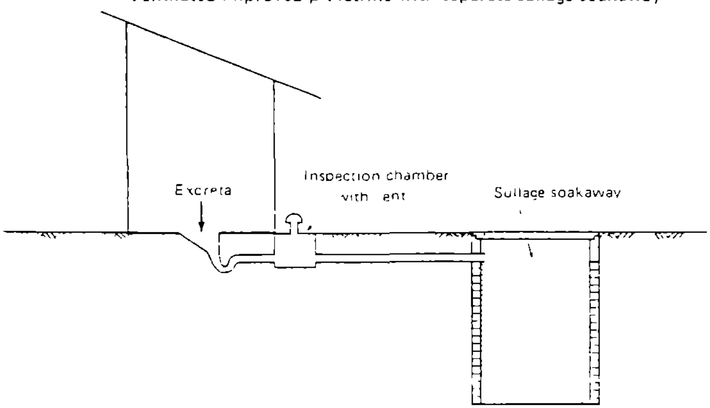
If the aqua-privy has to dispose of only a small amount of sullage, it is essentially equivalent either to a VIP latrine with a separate soakaway for sullage, or to a pour-flush toilet whose offset soakaway can also receive the sullage (Figure 6). These systems are less expensive than aqua-privies and less likely to give trouble The pour-flush toilet has a water seal which is much superior to that of the aqua-privy, it does not require a watertight tank, it can be located inside the house and it is more easily upgraded into a cistern-flush toilet Similarly, when sullage flows are high, the sewered pour-flush system is superior to the sewered aqua-privy



Aquaprivy



Ventilated improved pit latrine with separate sullage soakaway



Pour-flush toilet

Fig 6 Equivalence of an aquaprivy to a VIP latrine with a separate sullage soakaway, or to a pour-flush toilet (From Kalbermatten *et al*)

Cesspools

A cesspool is a covered chamber receiving all waste waters from one or more houses 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 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 is required and the system is therefore expensive and its functioning depends upon whichever local authority is operating the collection service The cesspool could then be considered as an expensive variation of the vault system

Compost toilets

Latrines can be designed in such a way as to permit the transformation of the excreta into a form of compost which can safely be used as a soil conditioner and fertiliser. If people need the compost, it will encourage them to empty the latrines regularly The twin pit latrine is in fact a kind of composting latrine

Experiments with other types in which the composting process is accelerated, thus permitting a smaller chamber and more frequent emptying, have shown them to be unsuitable for many developing countries, although one type has found widespread application and acceptance in Vietnam (Figure 7) and has been successfully tried in Guatemala. In the Vietnamese composting latrine there are two chambers, urine is excluded, ash is added after each use, and each chamber is sealed for two months when it is full, after which the compost is removed and applied to the land.

Obviously, latrines of this type cannot be introduced into a new area without an enormous supporting effort in communication, education, and evaluation to ensure that they are being properly used. The need for such a supporting programme increases the cost of compost toilets

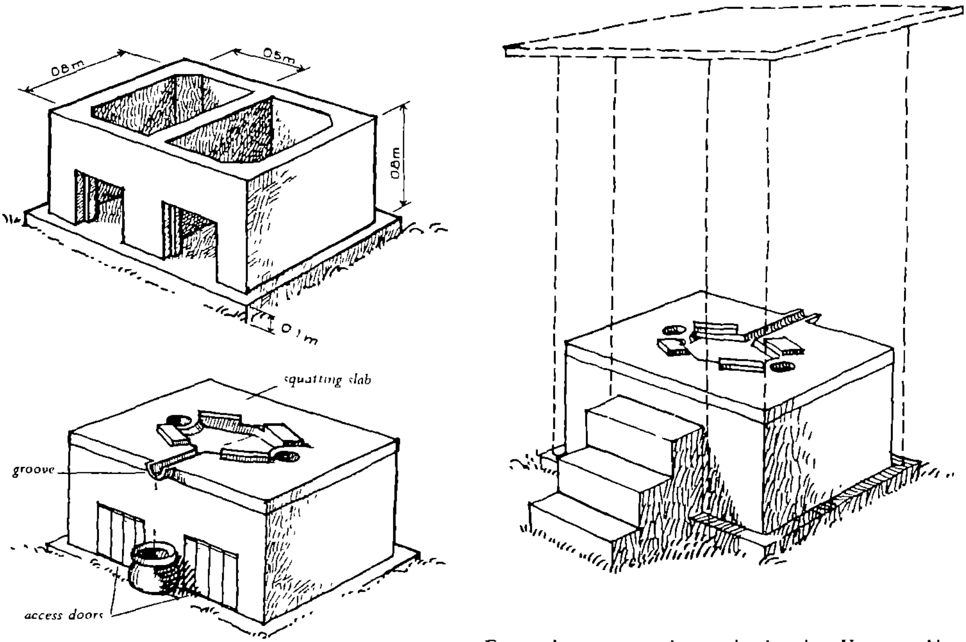


Fig 7 A composting latrine developed in Vietnam Although these have been used in Vietnam and Guatemala, attempts to apply this system in several other countries have been unsuccessful (From Winblad *et al*)

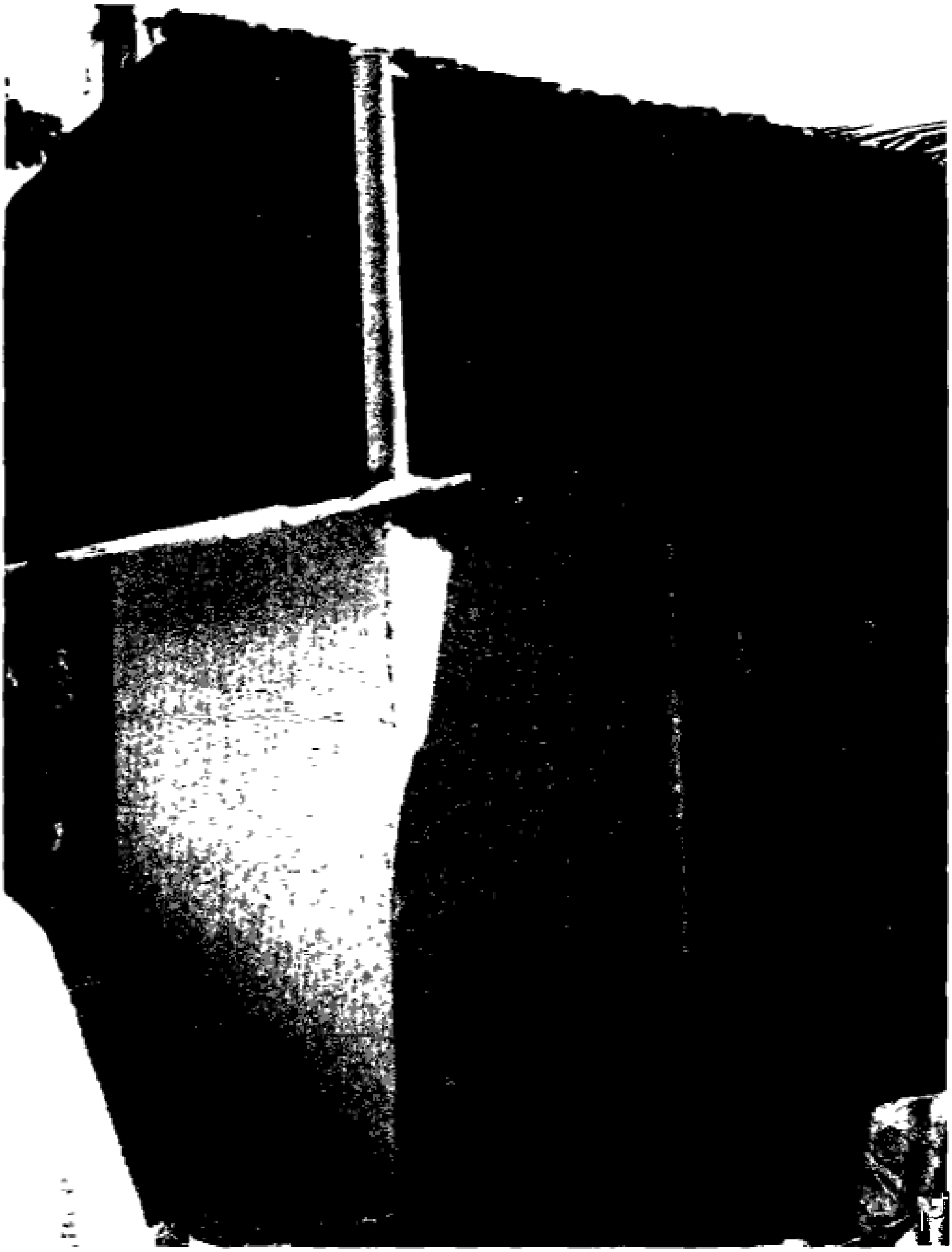


Plate 6 A VIP latrine built onto a house in a poor urban community in Brazil Note how the vent pipe is as high as the adjacent roof The pit is lined, to permit mechanical emptying and to protect the house foundations (Photo S Cairncross)

CHAPTER 3 CHOOSING A SYSTEM

3.1 INTRODUCTION

All of the systems recommended in Chapter 2 can be made to operate hygienically, so that the choice of the most suitable excreta disposal system for particular local conditions can be made on the basis of convenience, acceptability and technical feasibility.

A good indication of what is feasible can be gained from a detailed look at systems already in use locally, to see how they perform technically and how acceptable they are to the users You may also discover some ingenious features which are worth copying People with previous experience of latrine construction can also offer good advice, in almost any part of the developing world, *someone* has tried, successfully or not, to improve sanitation during the last few decades, and much can be learnt from their experience.

Moreover, a sanitation system is most likely to be easily acceptable if it builds on current practice An improvement to an existing type of latrine is usually much easier to introduce on a wide scale than a radically new system.

Technical feasibility depends on many factors (Table 4), of which the most important include the following

- cost and affordability,
- water availability;
- ground conditions;
- the risk of ground water contamination,
- population density;
- potential for future upgrading,
- re-use

These factors are discussed in the Sections below

It is essential to involve the potential users in the decision from the earliest possible stage, and it is often helpful to build several pilot models for demonstration purposes These can also be used to experiment with different construction materials and design modifications to find the version which is most suitable and most popular There is no need to limit the choice to a single system for a whole community, and there will often be advantages in offering two or more models from which each household can choose the one they prefer.

TABLE 4 Choice of sanitation system

Sanitation system	*Suitable for rural areas?*	*Pop density where suitable*	*Construction cost*	*Operation cost*	*Ease of construction*	*Water requirement*	*Permeable soil required?*	*Off-site facilities required*
Pit latrine	Yes	L	VL	L	Very easy	None	Yes	None
VIP latrine	Yes	L	L	L	Easy	None	Yes	None
Twin pit latrine	Yes	L/M	M	L	Needs builder	None	Yes	None
Pour-flush toilet	Yes	L/M	L	L	Needs builder	Water nearby	Yes	None
Septic tank and soakaway	Yes	L	H	H	Needs builder	Multiple tap	Yes	Sludge disposal
Small bore sewerage (sewered pour-flush)	No	H	H	M/H	Needs engineer	Yard tap	No	Sludge disposal, sewers, treatment
Sewerage	No	H	H	M	Needs engineer	Multiple tap	No	Sewers, treatment

H = high, M = medium, L = low, VL = very low

3.2 AFFORDABILITY

There is little use in promoting an excreta disposal system which people cannot afford to pay for Cost should therefore be a major consideration In general, low-income communities will not be prepared to spend more than about 2 to 3 per cent of their income on excreta disposal However, they may be prepared to spend larger sums over a short period of time, especially if credit is available to them at moderate rates.

The relative costs of different types of system will vary widely between different countries and regions of a country However, the results of a World Bank survey give a rough idea of the range (Table 5). Mean costs compiled from a series of case-studies in twelve countries are shown as percentages of the mean cost per household of a conventional sewerage system These figures include both construction and maintenance costs, and the cost of additional water where required. The numbers in brackets show the range between the various places studied.

TABLE 5 **Approximate relative costs per household of excreta disposal systems**

	Mean	*Range*
Improved pit latrines	7	(2-14)
Pour-flush toilets	5	(3-6)
Sewered pour-flush toilets	40	(31-48)
Septic tanks with soakaways	92	(76-98)
Conventional sewerage	100	(36-160)

Source Kalbermatten *et al* (1980), Vol 1

In more concrete terms, construction of a conventional sewerage or septic tank system is likely to cost over a thousand pounds per

Plate 7 A collapsed pit latrine The superstructure is unnecessarily massive and was placed on inadequate foundations above an unsupported pit This could have been prevented by a lining around the pit (Plates 8 and 9) (Photo R G Feachem) household, whereas a VIP or pour-flush toilet can cost about a hundred pounds or less. In rural areas where local materials are available free, latrines can be built very cheaply indeed

3.3 WATER AVAILABILITY

The wet systems depend on water for flushing, whether by pouring or from a cistern, and so the feasibility of these options depends on the reliability and level of service of the water supply On the other hand, in some cases the system is expected to dispose of waste water (sullage) as well as excreta, and where there is a multiple-tap level of water supply service the flow of sullage may be too large for some of the non-sewered systems In practice, users who can already afford a multiple-tap level of water supply will generally be able to afford one of the more expensive wet systems.

This means that, as a rule, only a few of the possible options will be appropriate for users with a given level of water supply service.

Multiple tap

Users with multiple taps, showers, etc in their houses are likely to prefer and afford a cistern-flush system, and to produce large amounts of waste water; typically at least 100 litres per person per day, of which 30-50 per cent will come from the toilet. This will limit their choice, apart from conventional sewerage, to septic tanks with soakaways or with small bore sewers

Yard tap

Users at this level have a single source of water in or near the house. This may be a tap, a well, a rainwater cistern or some other private water supply If the water is not stored in an elevated tank, it will not usually be possible to operate a cistern flush system. Pour-flush toilets with soakaway pits or with small bore sewerage will be more appropriate.

Sometimes there may be special reasons for preferring a dry system; for example, if the soil does not have sufficient infiltration capacity to absorb all the waste water produced, but piped sewerage is *not* affordable. Even then, thought must be given to disposal of sullage – the wastewater from bathing, laundry etc

Off-site water source

If users have to leave their household yard to collect water from a public source, such as a well, stream or standpipe, a wet system is not usually advisable. Exceptionally, where water is used for anal cleansing and the water source is within a few hundred yards, pour-flush toilets may be considered, but a dry system will generally be more suitable

3.4 GROUND CONDITIONS

All of the systems involve some excavation, so that the local ground conditions are bound to affect them. It is more difficult to excavate pits and pipe trenches in areas of rock or loose sand, and the extra cost may influence the choice of sanitation system. Moreover, the feasibility of some on-site disposal systems will be limited if the local soils have not enough infiltration capacity to absorb the liquid wastes No large-scale sanitation programme should therefore be undertaken without a thorough soil survey However, a rough estimate of a soil's infiltration capacity can be made quite easily.

Infiltration capacity

The infiltration capacity of a soil depends largely on the size of its particles. Sand particles are larger than 0 05 mm in diameter, clay particles are finer than 0.002 mm, and those between these two sizes are known as silt.

The soils with the highest infiltration capacity are sands. Some finer soils may contain visible sand particles, but they can be distinguished from a true sand by rubbing them in the palm of the hand, in which case they will stain the skin, while the coarse grains of sand will not Silts and loams, which have a mixture of particle sizes, will have lower infiltration capacity than sands The least permeable of all are the clays, which can usually be distinguished from other soils by the following test

Prepare sufficient soil to form a ball about 20 mm in diameter by moistening with water. Place the prepared sample in the palm of one hand, and shake vigorously by bringing the hand down sharply to hit against the other hand several times If the soil is a clay, its appearance will remain unchanged. If not, water will come to the surface of the sample producing a smooth shiny ('livery') appearance. If the sample is then squeezed between thumb and forefinger of the other hand, the surface water will disappear so that the surface becomes dull. However, if the sample is of a clay this will not occur.

Approximate rates of infiltration for sewage and for sullage in the three types of soil are given in Table 6. The infiltration rate for sewage (in a soakaway from a pour-flush toilet, for instance) is lower because the sides of the pit tend to become more clogged with organic matter after a few months' operation

TABLE 6 **Approximate infiltration capacities of various soils**

Soil type	*Infiltration capacity (litres/m² day)*	
	Sewage	*Sullage*
Sands	50	200
Silts and loams	30	100
Clays	10 or less	50 or less

Where the infiltration capacity is low, a larger and more expensive soakaway is required. In some clays, the infiltration capacity is negligible so that on-site disposal of even a small amount of sullage is out of the question. Where clay soils are found, therefore, more detailed site investigation is especially important to establish the real infiltration capacity of the ground.

Liquid load

The infiltration capacity of a pit or soakaway must be at least equal to the amount of liquid it must absorb. A typical load on a pit latrine used by five to ten people is 8 to 15 l/day Where water is used for anal cleansing, this would increase to 30-60 l/day In a conventional pour-flush toilet, it would be 50-100 l/day Where a soakaway pit or trench is also to receive sullage, the load will be roughly equal to the volume of water used daily in the house, and therefore will depend on the level of water supply. Typical volumes of sullage water production are·

communal wells and hand pumps	10 l/person.day
communal standpipes	15 l/person.day
household wells, yard tap	30-50 l/person.day
multiple-tap private connections	50-300 l/person.day

If the expected liquid load means that the size of the soakaway required is too expensive or too large for the space available, then off-site disposal may be worth considering

High water table

If the water table is very near the ground surface, a soakaway may not be able to absorb much liquid without overflowing. Some ways to deal with this problem are described in Chapter 4. There will also be a greater risk of ground water contamination, which is discussed below.

3.5 RISK OF GROUND WATER CONTAMINATION

Disposal of excreta into the ground will always present the danger of polluting water sources such as nearby wells, and also water mains in which sufficient water pressure is not maintained throughout the day. In extreme cases, this may make on-site disposal systems unsuitable. However, the risk can usually be avoided by following a few simple rules

Pit latrines and soakaways should not be built within 15 m of a well or other source of drinking water, and should not be located uphill from the water source The danger of pollution is increased if the pit is dug down near to the water table or to fissured or weathered rock The danger is also greater when large volumes of water are pumped from the well.

Bacteria will not penetrate more than 1-2 m in most soils above the water table, but they have been known to travel over 100 m in gravel below the water table and through cracks in rock If bacterial pollution reaches the water table, it may spread as far as the distance travelled by the ground water itself in ten days This distance depends on many factors, including the soil type, slope of the ground, and the amount of water likely to be pumped from any nearby well It can be estimated by an engineer, and should be the minimum spacing allowed between a source of ground water contamination and the nearest well, borehole or water main

Of course, if the ground water is not used for domestic purposes, contamination of it by sanitation systems may not matter at all.

3.6 POPULATION DENSITY

For individual households in isolated sites, an on-site disposal system will be appropriate, although an institution such as a school or clinic with multiple tap water supply may produce a large enough flow of sewage to justify building a small treatment plant.

On the other hand, when people live close together so that population density is high, this affects the choice of sanitation system in several ways First, there may not be sufficient space for on-site disposal. There may also be an increased risk of ground water contamination (see above). Second, more people can be served by a given length of sewer pipe, so that sewered systems are less costly. Third, there may simply not be enough space to build a latrine in or near to each house, so that some type of communal latrine is unavoidable

On-site disposal

The single pit latrine used in rural areas has to be moved to a new site each time the pit fills up. In urban areas, there may not be enough space to do this Digging a new pit within 2 m of an existing, full pit is extremely dangerous, as the wall of soil left between them can easily collapse If the pit is lined, it can be emptied, but if the expensive equipment to empty it mechanically is not available, the pit must be emptied by hand, and this exposes the emptiers to contact with fresh excreta. The solution is to build a twin pit latrine (Section 2.2) and ensure that someone has the capacity and the motivation to empty the pits alternately and dispose of the contents. Pour-flush latrines usually have two pits for the same reason, with the advantage that the pits can be under the road outside the plot, or even under the floor of a room in the house.

A septic tank system may require quite a large area for the soakaway, depending on the soil conditions and the flow of sullage for disposal The soakaway should not be allowed to take up more than half the space available, so that there is room to build another if the first one becomes blocked by clogging of the surrounding soil. If sufficient space is not available on the average plot, sewerage may be more appropriate. Small bore sewerage is particularly appropriate when septic tanks already exist.

Sewerage

The cost and feasibility of sewerage depends very much on the local topography Where the land is flat, more expensive deep trenches and pumping stations are needed than in places where existing slopes can be used to advantage and there are suitable sites in the low-lying areas for treatment and discharge of sewage

Moreover, the codes of practice prevailing in most countries are unnecessarily conservative and the cost of sewerage can be reduced by as much as 50% by using smaller diameters (down to 100 mm), flatter gradients (1 in 170) and laying pipes at relatively shallow depths If the pipes are laid under gardens, not streets, they can be less than a metre deep At population densities of 100 inhabitants per hectare and above, the cost of this 'shallow' sewerage can be similar to the cost of comparable on-site systems.

Communal latrines

Where there is not enough space to build a latrine for every family, for example in slum tenements, communal latrines may be a solution of last resort Even so, they are likely to

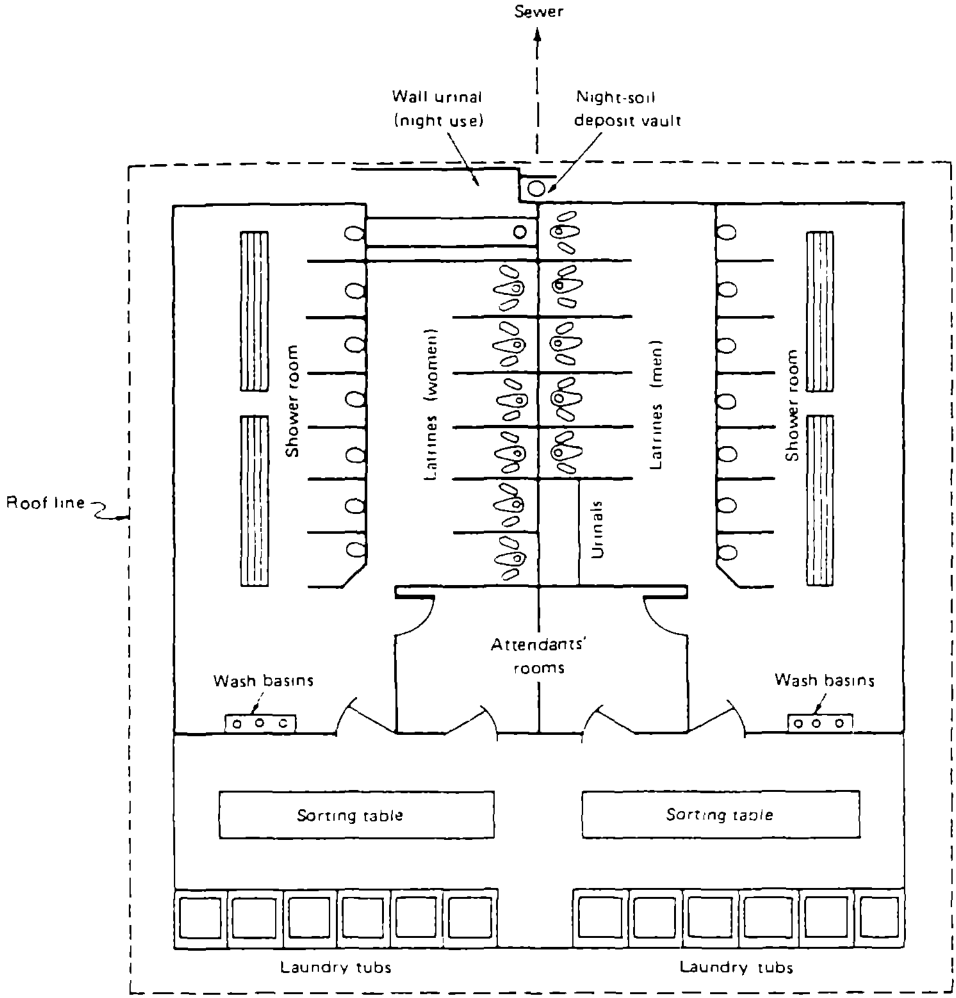


Fig 8 Plan of a communal latrine and washing facility serving about 300 people A large water storage tank is also needed if a constant water supply cannot be guaranteed (From Kalbermatten *et al*)

need between 5 and 10 per cent of the total land area available Moreover, they have many disadvantages and the decision to introduce them should not be taken lightly. The basic problem is that there is little commitment by individual users to keep them clean and operating properly One solution is to have a communal latrine block, but reserve each cubicle for use by one family (or at the most two or three families) who are responsible for cleaning and maintaining it.

If there are not to be 'private' cubicles in this way, it is essential to provide one or more well-paid attendants to keep the installation in good order, and lighting and water supply must be provided. If necessary, a water storage tank is needed to ensure that water is available for 24 hours a day. The latrines should also be regularly inspected by the employers of the attendants, to ensure that they are being well maintained

Additional problems are:

(i) the lack of privacy
(ii) the difficulty of their use at night and in bad weather, especially by children, the sick and the old;
(iii) they cannot be upgraded to individual household latrines

The ideal type of toilet to install is a pour-flush or low-volume cistern-flush toilet, at the rate of one compartment for every twenty-five people served If showers and clothes-washing facilities are not available in individual households, these should also be provided. Figure 8 shows a layout for a communal sanitation facility serving about 300 people

3·7 UPGRADING

The sanitation systems in use in the industrialized countries evolved over more than a century of successive improvements. It would be simplistic to think that sanitation in developing countries should be upgraded in a single step, and most unjust to the many people who cannot afford the improvements which in the long term would be most desirable. It is clearly preferable to start with a modest improvement and upgrade it progressively over a period of years or decades

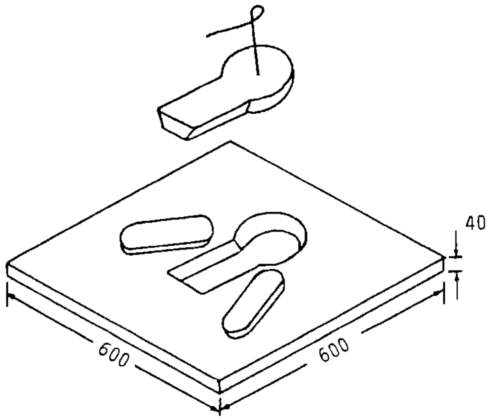


Fig 9 A small squatting slab which can be placed over the drop hole of an existing latrine and fixed in place with mortar It provides
- a smooth hard surface sloping down towards the drop hole, which is easier to clean,
- raised footrests to help the user to avoid fouling the edge of the hole,
- a drophole of correct size to give security to small children,
- a tight-fitting lid to control flies and cockroaches

Thus, the cheapest and simplest measure will often be a minor improvement to an existing type of latrine, such as an improved squatting slab (Figure 9) or a ventilation pipe On the other hand, a new system should be designed to allow for possible upgrading in the future. Figure 10 shows several possible upgrading routes for a sequence of incremental improvements.

3·8 RE-USE

Human wastes are a valuable natural resource and can be used in three main ways. agriculture, biogas production 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

Agriculture

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 serious health hazards to agricultural workers and to the consumers of the crops grown, and is not recommended. Nightsoil should be composted with organic refuse and vegetable matter before application to the land. The contents of pit latrines and soakaways which have been closed off or buried for at least a year will make a fertilizer and soil conditioner which is as effective as fresh nightsoil but is also harmless.

Water-borne wastes are particularly useful where irrigation water is scarce. But they should not normally be applied without prior treatment. Treatment in a septic tank or conventional sewage works *will not* remove the health risk. Only treatment in waste stabilization ponds (see Section 4.6) can reliably render the sewage suitable for irrigation.

Spray irrigation involves a risk of the air-borne spread of disease pathogens and is not recommended. From a public health viewpoint, it is preferable 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 unless specialist advice is followed on how to make the practice safe.

Biogas production

Nightsoil, mixed with animal and other wastes, can be used to generate methane, or 'biogas'. A typical mix would be one part of nightsoil to three parts of animal manure and one of vegetable matter such as crop stalks, diluted with an equal quantity of water. This technique is most commonly found in China and India, where the biogas is a by-product of the treatment of the wastes to make fertilizer. Figure 11 shows a typical biogas plant. In India it has been found that a biogas plant of 7-10 m^3 capacity, in which a family's excreta are supplemented with the dung from three or four cattle, can provide about 1 m^3/day of biogas, sufficient for cooking and lighting for

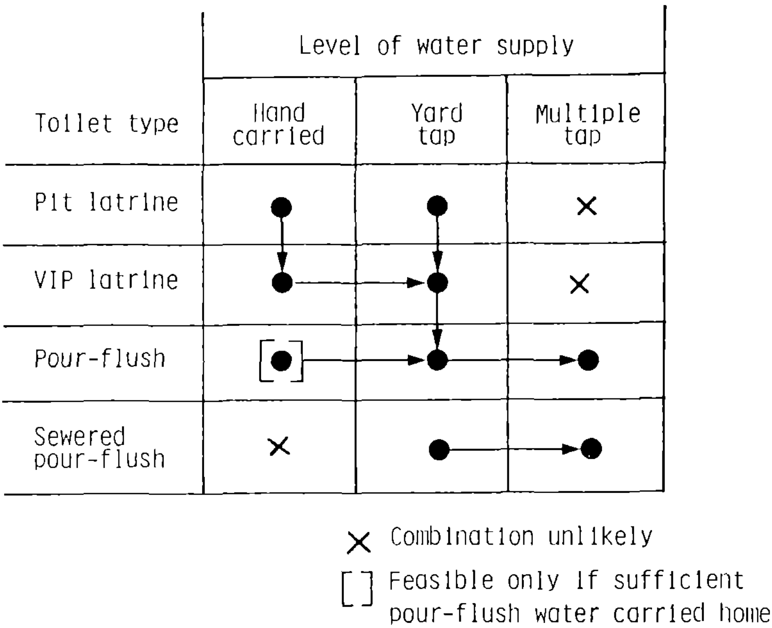


Fig 10 Sanitation upgrading sequences

a family of 5 people. As the waste is diluted and fed into the digester at one side, the effluent is removed at the other, and carted away for use as fertilizer.

A biogas plant requires careful control and is only appropriate where conscientious operation and maintenance can be guaranteed. Anyone planning to build one should take advice from others with first hand experience and consult some of the technical literature. (See references at the back of this Bulletin)

Aquaculture

Ponds containing human wastes are rich in aquatic life provided they are not overloaded In particular, they support large blooms of green algae These conditions are perfect for the growth of certain types of fish, especially carp and tilapia. As much as 1-5 tons of fish per hectare per year can be produced in ponds enriched with excreta. Ducks will also thrive, together with fish in such ponds

It is common in some countries, particularly in South East Asia, 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. However, it is preferable to grow fish in the maturation ponds in a series of waste stabilization ponds in which the wastes are treated (see Section 4.6)

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 the fish are for human consumption, it is important that they should be well cooked If not, they may act as the main transmission route for various pathogens, most notably the oriental liver fluke (*Chlonorchis sinensis*).

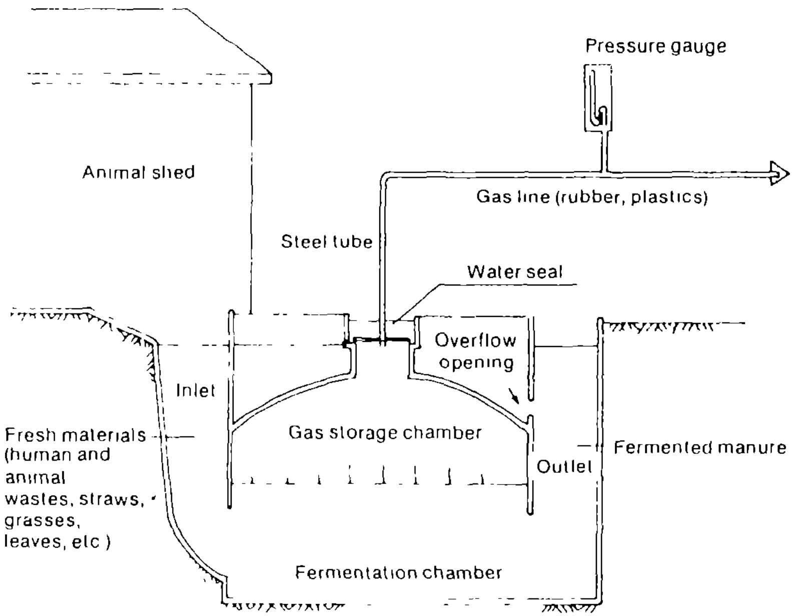


Fig 11 A large biogas plant as used in China This design is cheaper than the better-known Indian version with a rising metal dome, as it can be built mainly with local materials (From IDRC, 1981)

Plate 8 Open jointed brickwork lining in a round pit in Zimbabwe. A round pit is the most stable shape, so that no cement mortar is needed (Photo D D Mara)

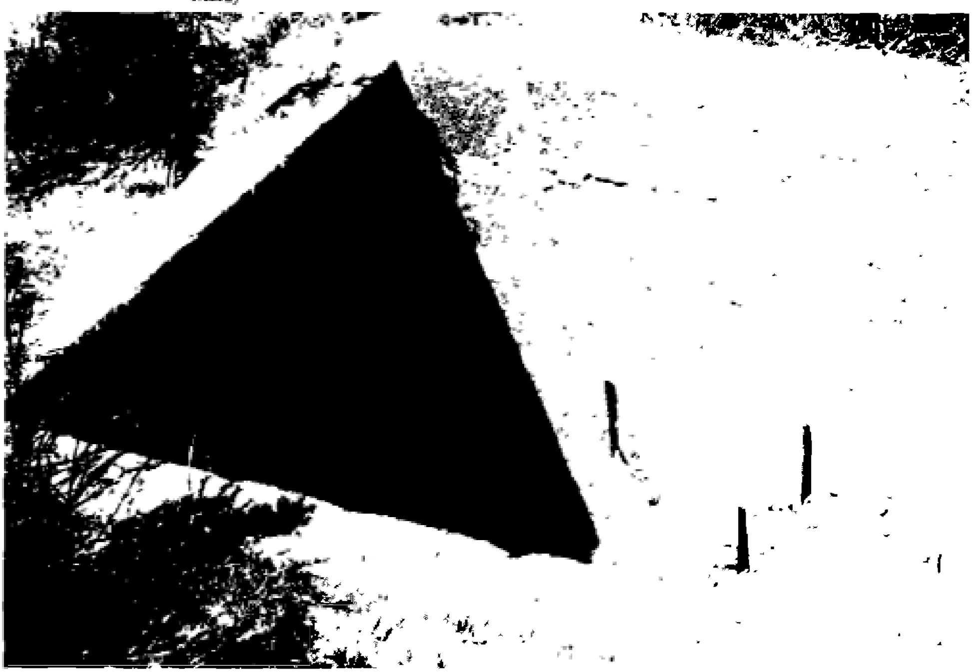


Plate 9 Concrete block lining in a rectangular pit in Botswana Note that the vertical joints in the lower courses of blockwork have been left without mortar to allow liquids to pass into the soil (Photo D D Mara)

CHAPTER 4 DESIGN AND CONSTRUCTION

4.1 PIT LATRINES

The pit

Unless there is good reason to be sure the pit will not weaken adjacent house foundations, it should be at least 3 m from the nearest wall. If the pit has a strong lining, this distance can be reduced slightly, but not to less than half the pit depth. The pit should also be at least 15 m from the nearest water source (Section 3.5). Since many pit collapses are caused by surface water flowing past the latrine or into the pit during heavy rainfall, a pit should never be located in a natural line of drainage or depression.

The pit volume should be at least 0.06 m^3 per person for every year of anticipated life, not including the top 0.5 m as the pit must be emptied or filled with earth before it is completely full. Thus, a pit 1.1 m in diameter and 3 m deep can serve a family of five for 6 years. A further 50 per cent should be added where bulky materials, such as stones, maize cobs, or cement bags are used for anal cleaning.

Obviously, the larger the pit, the longer it will last. But if the pit is very wide, it becomes difficult and expensive to build the latrine floor to span across it. Typical dimensions for the pit would be 3 to 7 m deep and about 1 m across, with 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 inexperienced workmen. If it is unlined, 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.

Unstable ground

In sandy or unstable soils the sides of the pit should be strengthened against collapse by building a lining (Plates 8 and 9) or a collar around the upper part (Figure 4). A lining is particularly important where the pit will be full of water, but it should not prevent the seepage of fluids into the ground.

A simple test for the stability of a soil is to roll several moist samples of it into cylinders about 5 cm long and 2 cm in diameter. Dry them in the sun for two days, and then try to crush them between the thumb and fingers. Unstable soils such as sands will crush easily, but stable soils will not. If existing latrines have been known to collapse in the area it is usually wisest to assume the soil is unstable.

The lining can be made of concrete rings, cement blocks, bricks, stone rubble, rot-resistant timber such as mangrove poles, or even perforated oil drums. If concrete rings are used, they should have plenty of holes to allow liquid matter to pass through them into the soil. If blocks, bricks or masonry are used, the vertical joints of the lining should only be mortared for the top half metre of the lining, for the same reason. If the soil is so loose that it may run in through the open vertical joints, fine gravel should be placed in a 100 mm space between the soil and the lining to prevent this.

For a pit in moderately stable soil, a collar can be cast in concrete *in situ*, possibly in a carefully excavated 0.2×0.2 m trench before digging the pit. Another precautionary measure is to plaster the walls of the pit with cement mortar (1 part cement, 5 parts sand) and a thickness of 1 cm. The plaster should have holes to allow water seepage through it, and may be reinforced with chicken wire mesh.

Borehole latrines

Where ground conditions allow and where there is no danger of contaminating water supplies (see Section 3.5), it is possible to avoid the need for a structurally strong latrine floor spanning the pit by drilling a hand-augered borehole about 6 m deep and 400 mm in diameter instead of digging a pit (Figure 12). Although the borehole latrine has a smaller volume and therefore fills up faster than a pit, it is faster to install in large numbers and requires only a small and relatively portable slab. It is particularly appropriate following disasters where large numbers of latrines must be rapidly installed.

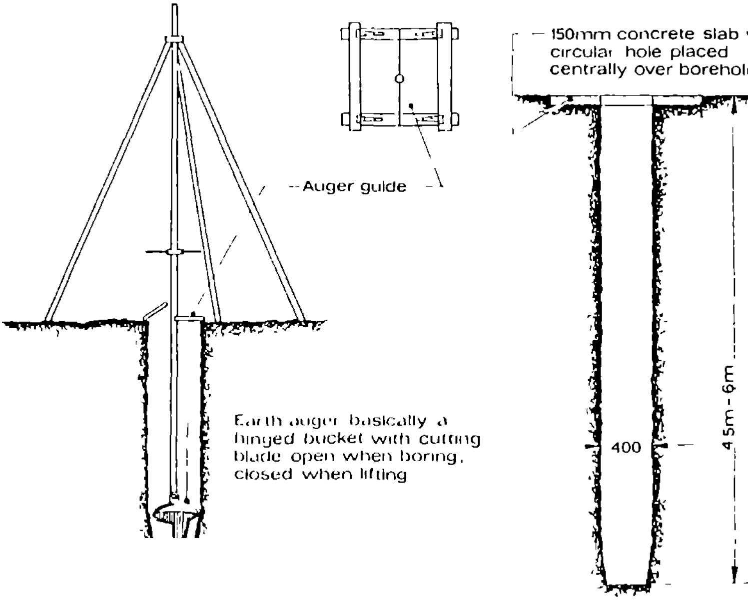


Fig 12 Construction of a bored-hole latrine (From the Manual of Army Health)

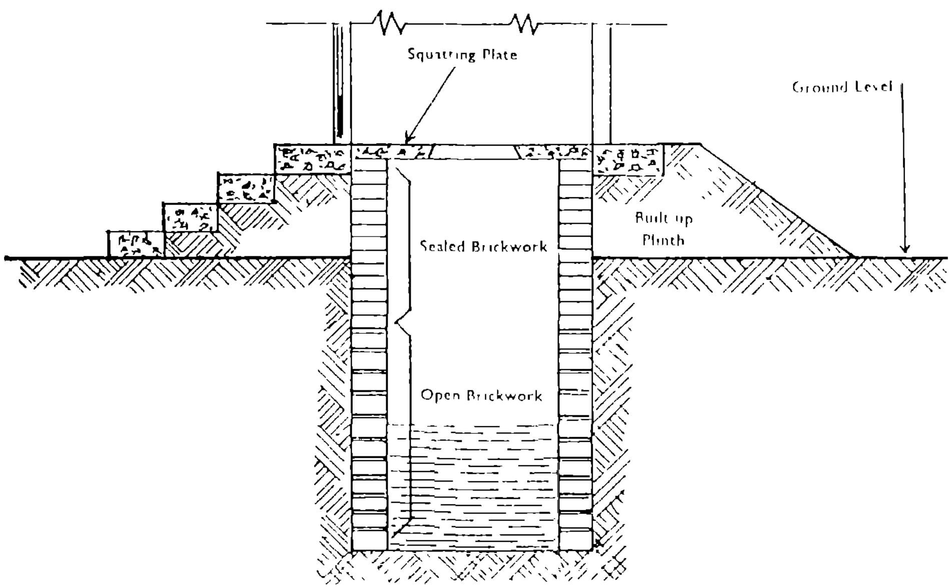


Fig 13 A built-up pit latrine suitable for areas where rock or the ground water is near the surface Where contamination of the ground water would pose a health risk, the bottom of the pit should be sealed with puddled clay or cement mortar, and a 50cm thick envelope of fine sand placed around the lining as in Fig 22 (b)

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 quinquefasciatus* mosquitoes (which in some parts of the world can 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 13 The built-up plinth may be up to 1 m high and the water-tight lining of concrete or sealed brickwork should extend down at least 0.6 m below ground level

Even if the water table sometimes rises to within 2 m of the botton of the pit, pathogens in the groundwater are not likely to travel farther than 15 m from the latrine unless the soil is coarser than medium sand, that is, unless most soil particles are larger than 0.2 mm. Particles this size can be seen with the naked eye. If the ground water table is high and the soil is coarse, the following measures should keep the distance travelled by pathogens to within 15 m of the pit

(i) seal the bottom of the pit with wet clay, cement mortar or plastic sheeting,

(ii) dig the pit 1 metre larger in diameter than the lining, and fill the 500 mm space between the lining and the existing soil with fine sand.

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

The floor

The simplest and cheapest improvement to a pit latrine is to provide it with a prefabricated floor, in the form of a squatting slab (Figure 14) or with a seat This will make the latrine structurally safer and more agreeable to use than one improvised with local materials, will prevent the transmission of hookworm, and will permit a small measure of fly control through the use of a lid The need for steel reinforcement can be reduced or even avoided by making the slab slightly domed or conical in shape (Figure 15).

Concrete slabs of the necessary size are heavy and it is sometimes an advantage to cast them at the site. If the slab is round it can be transported small distances by rolling it like a wheel Slabs can also be made in two parts for easier carrying. If so, they should have an overlapping joint (as in Plate 10), which should be sealed against flies, preferably with cement mortar

In some countries, a seat is more acceptable than a squatting slab in spite of its higher cost. It also has the advantage that it is less likely to be fouled by excreta which miss the hole. Moreover, when a toilet with a squatting slab is cleaned, grit and other debris on the floor will be swept down the hole, tending to fill up the pit prematurely. If a squatting slab is used, the drop hole should not be wider than 170 mm so that it is safe for use by children It should be at least 360 mm long and there should be raised foot-rests to prevent fouling.

The upper surface of the floor slab should be finished smooth in cement rendering. If a raised seat is not used, it should slope down towards the drop hole and should preferably be painted 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. Beneath the floor, a solid, impermeable base should preferably encircle the opening of the pit (Figure 16). 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 earth dug from the pit should be rammed to form a platform extending 1 metre around this base The floor of the latrine is placed on this platform, and should be sealed around the edges to prevent flies from entering or leaving the pit.

Superstructure

This should be built in such a way that there is no earth exposed between its walls and the edge of the floor slab. Any space between should be filled in with smooth-finished cement. The walls should be high enough for privacy, but should stop below the roof so as to provide good through ventilation It may help if the superstructure is designed 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).

Fly problems

Flies often lay their eggs in faeces, and poorly built latrines can lead to an increase in the population of flies carrying faecal pathogens. Pouring insecticides into the pit to kill flies is not recommended. Although it will kill flies in the short term, it may permit a greater resurgence later, by killing the flies' competitors and predators

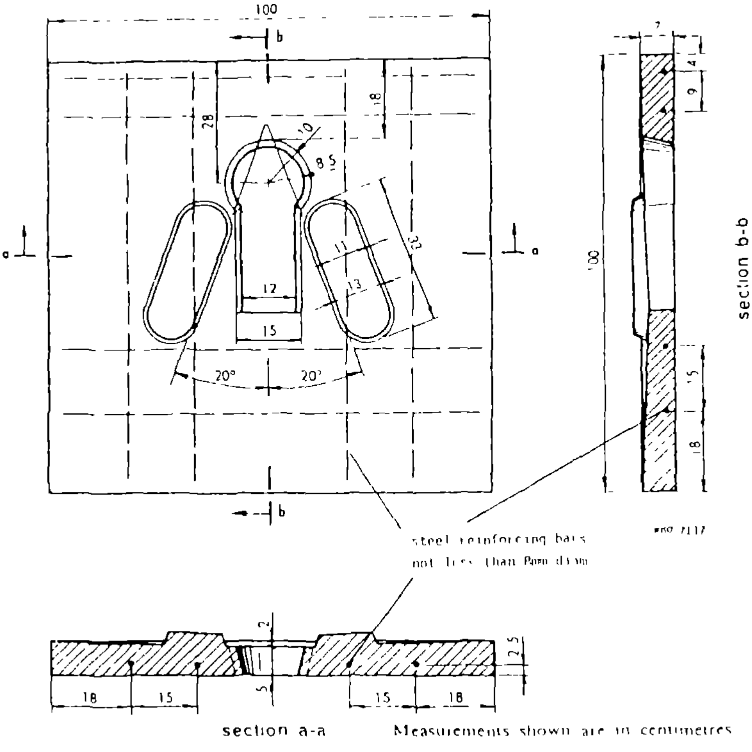


Fig 14 Square reinforced concrete squatting slab for a pit latrine (From Wagner & Lanoix)

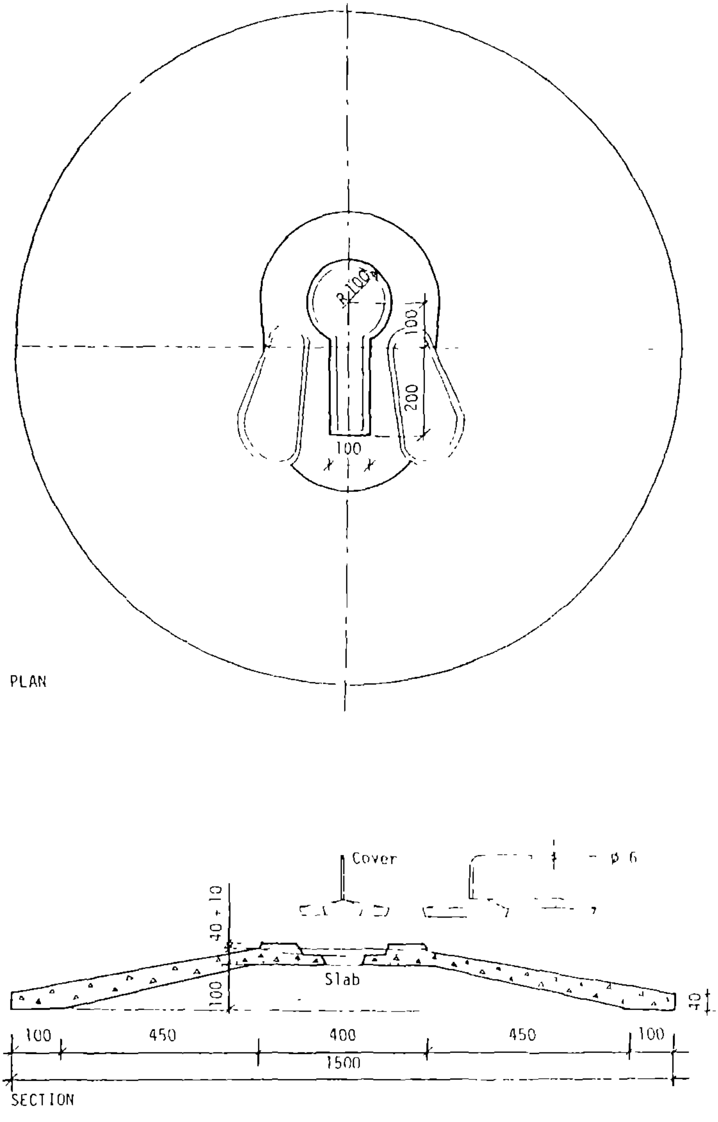
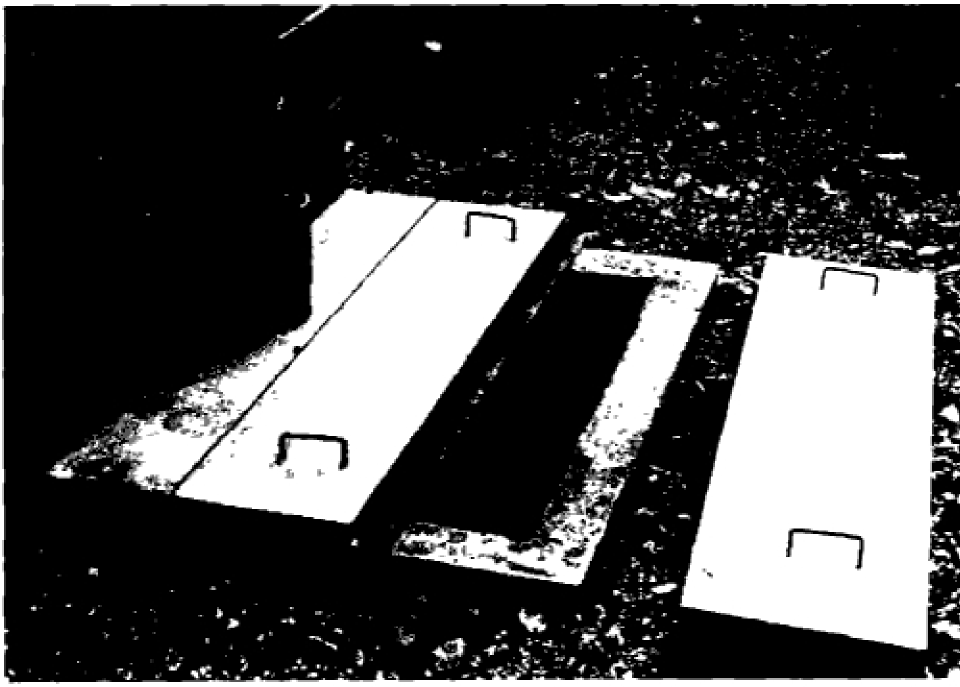


Fig 15 A round, conical unreinforced concrete squatting slab developed in Mozambique (dimensions are in mm) (From Brandberg)



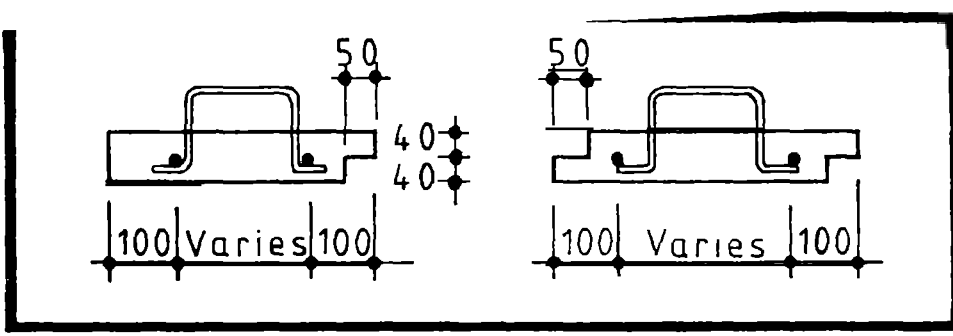


Plate 10 Access to one pit of an alternating twin pit VIP latrine (Photo by D D Mara of a pit at UK Building Research establishment Crown Copyright reserved)

Insecticides have been used successfully in this way to control mosquitoes in flooded latrines, but their use in a continuous programme is not recommended It is likely that the regular spraying of latrines in Dar-es-Salaam, Tanzania, over the last ten years was a major cause of the development of resistance to organophosphate insecticides in the local *Culex quinquefasciatus* mosquitoes. There is also a danger that the insecticides may pollute nearby water sources.

A simple fly control measure is to drape pieces of sacking soaked in used motor oil around the edges of the pit, hanging down by at least 300 mm and extending out horizontally under the floor by at least 500 mm (see Figure 16) This is supposed to interrupt the emergence of flies hatched from the excreta, which spend a period of their development buried in the pit wall However, it does not seem to be as effective as the VIP system (Section 4.3).

4.2 TWIN PIT LATRINES

The use of a pit latrine with a permanent superstructure presupposes of course that arrangements have been made to empty the pit when it is full The emptying of a pit latrine by mechanical means is not easy If a vacuum tanker truck is to be used, water must usually be added first and the pit contents mixed up with it to make them more fluid. In this case, the pit should normally have a lining One modification which makes mechanical empty-

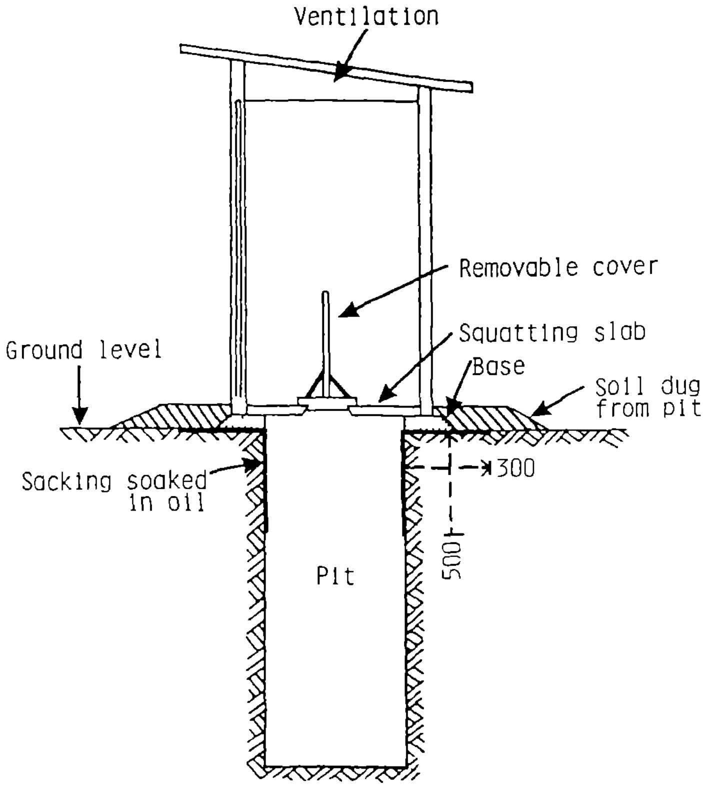


Fig 16 Section showing construction of a basic unventilated pit latrine The oil-soaked sacking is a fly control measure used by the British army, but it is not always effective (dimensions are in mm)

ing easier is to have an impermeable lining, so that the pit contents stay wet, and drain excess fluids to a separate soakaway (see *VIP latrine with soakaway*, below).

However, the need for sophisticated equipment such as pumps and tanker trucks can be avoided by using two pits alternately. The excreta are never handled until they are at least twelve months old, when only a few roundworm eggs at most will still be alive, and the pit contents have been transformed into harmless and inoffensive humus which can be used as fertilizer. No other materials need be added to the pits.

In order to allow for some flexibility in emptying time, each pit should be large enough for two years' use This is less than is needed in a conventional pit latrine, so that the two pits can be shallower. They can often be less than 1 metre deep. This can be useful in difficult ground where there is water or hard rock near the surface The pits may extend either to each side of the superstructure or to the rear (Figure 17), with a cover which can be removed for emptying. This cover is usually made of reinforced concrete in three or four sections, whose edges interlock (Plate 10) to give an effective seal against flies and smells They should be fixed in place with lime or cement mortar after each time they are removed. The floor of the latrine can be made in two halves, one with a drop hole or seat and one without, which are exchanged when one pit fills up; this will help to ensure that only one pit is in use at any time.

Householders may empty their own pits by hand if they are able and keen to use the humus-like material as fertilizer on their plots and if they do not consider this operation unacceptable. Alternatively, pit emptying may be a municipal function which may well have administrative difficulties in practice, or it may be carried out by the private sector, for example by local farmers or by a private concern which sells the material to local farmers or otherwise disposes of it. In any event,

Plate 11 A crack like this in a septic tank cover can create an unbearable mosquito nuisance for the owner and his neighbours After desludging, septic tanks should be carefully sealed, and preferably covered with earth (Photo S Cairncross)

the arrangements for removing and disposing of the pit contents must be planned before twin pit latrines are built on a wide scale.

Twin pit latrines are already traditional in some parts of the world; for example, in the state of Santa Catarina in Brazil The addition of vent pipes to transform them into VIP latrines is relatively inexpensive and reduces fly and odour nuisances.

The ventilation process can be made to work so effectively that VIP latrines can even be built into the house, as has been done successfully in Brazil and Ghana. However, special care is needed to avoid undermining the house foundations, and provision made for emptying the pit when it fills.

4·3 VIP LATRINES

The two principal disadvantages of the conventinal pit latrine – namely that it smells and produces hundreds of flies (or mosquitoes) a day – are reduced in the types known as ventilated improved pit (VIP) latrines The single-pit version is shown in Figure 4 Due to the action of wind passing over the top of the vent pipe, the air inside rises and escapes to the atmosphere, so creating a downdraught of air through the squatting slab or seat This circulation of air effectively removes the odours emanating from the faecal material in the pit.

The vent pipe also has an important role to play in fly control. Female flies, searching for an egg-laying site, are attracted by the odours from the vent pipe but are prevented from flying down the pipe by the fly screen at its top (Figure 4). Nonetheless, some flies will enter via the drop hole and lay their eggs When new adult flies emerge they instinctively fly towards the light; however, if the latrine is suitably dark inside the only light they can see is that at the top of the vent pipe If the vent pipe is provided with a suitable fly screen at its top, the new flies will not be able to escape and they will eventually fall down and die in the pit The fly screen should have a 1 mm square or 1×1.5 mm mesh, and should preferably be of glass fibre reinforced plastic or (best of all) stainless steel, so as to resist the corrosive gases emerging from the pit and the damaging effect on plastics of the sun's radiation. It should be checked for holes at least once a year and replaced if necessary At the same time, a bucket of water should be poured down the vent pipe to clear it of cobwebs.

Superstructure design

More usually, the VIP is a separate structure near the house, in which case the ventilation process will be helped if the entrance faces into the prevailing wind.

The superstructure must be relatively dark inside, so that the brightest light visible to young flies in the pit is from the top of the vent pipe, and not from the drop hole. This does not mean it must be pitch dark, but if there is a door it *must* be kept closed when the latrine is not in use. This can be helped by rising butts (hinges which make the door rise as it opens), by a spring or by a counterweight on a string.

The closed door is to keep out light, not air There should be an opening somewhere in the superstructure (usually above the door) for air to enter and maintain the draught down the drop hole and up the vent pipe. The area of this opening should be at least 3 times the cross-sectional area of the vent pipe.

It is possible to avoid the need for a door while giving complete privacy by the use of a superstructure with a spiral shape (Figure 4). This has some advantages because doors are not always left closed and are sometimes stolen, and also because wood is expensive and hinges rust

If these conditions are observed, the superstructure can be built in a wide variety of shapes and materials, including brick, ferrocement, or mud and wattle It is generally most appropriate to use the same materials and building techniques already used for houses as these have already been tested successfully under local conditions and the necessary skills to build and to repair them are already in the community.

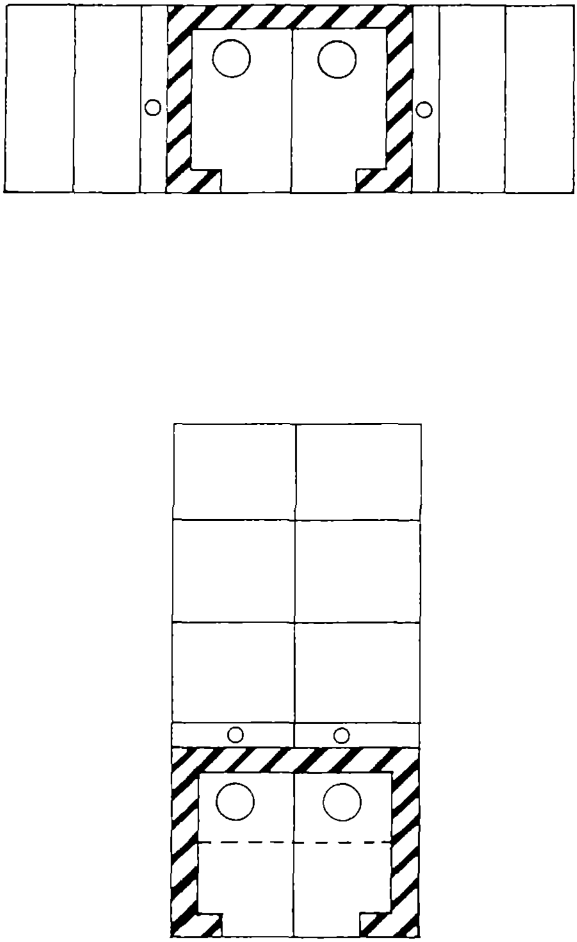


Fig 17 Alternative arrangements for twin pit VIP latrines (From Mara, 1984)

Vent pipe design

For the vent pipe to work efficiently it should rise 0.5 m above the roof of the latrine (If a conical thatched roof is used, the top of the pipe should reach the same level as the apex of the roof) The vent pipe should also be at least 2 m from any obstructions such as tree branches which might interfere with the wind passing over it Building the latrine under trees will not only impede the wind but also increase the probability of fallen leaves blocking the vent pipe

In areas where there is hardly ever even a gentle wind (average wind speed under 0 5 m/s), the outside of the vent pipe can be painted black so as to gain warmth from the sun. This will cause a slight updraught of air in the pipe in the absence of wind.

A wide variety of materials has been used successfully to make vent pipes, including plastic (PVC), asbestos cement, brick masonry, blockwork, reed matting rolled and covered with plaster, hessian (sacking) supported on steel mesh and plastered, and even ant hill soil Large diameter bamboo could also be used after removing the dividing membranes PVC becomes brittle when exposed to bright sunlight, so it is better to use a grade of PVC with a special stabilizer to prevent damage by sunlight, if this is available Pipes made from thin galvanised steel sheets are not recommended as they will quickly become corroded, aluminium sheet, although not ideal, may be better. The cost of the pipe is especially important in rural areas, where it may account for half the cost of the whole latrine

The diameter of the pipe depends on the material used. If the inside is rough, this will slow down the movement of air so that a larger pipe is needed to give adequate ventilation. The minimum internal size should be as follows.

Plastic, or asbestos cement	100 mm diameter
Brick	190 mm square
Plastered reed or hessian (and other rural types)	200 mm diameter

Note that these are *minimum* sizes Slightly larger sizes are preferable, if at all possible, especially if the location is relatively sheltered from the prevailing wind

To make a vent pipe of reed matting, take local reeds about 1 cm thick and tie them together with wire or string to form a mat measuring 2.5 m by 1 m. Then roll this mat around four or five rings made of green saplings to form a tube about 30 cm in diameter. Then fix the fly screen to cover one end, and apply cement mortar (1 part cement, 3 parts sand) to the outside of the tube along its whole length but only around half its circumference. When this has hardened, fix the vent pipe in position with the mortared side next to the latrine wall. Then apply the mortar to the other (outer) side. The same method can be used with thin poles, bamboo sticks, or strips 1-2 cm wide cut from larger bamboo poles

A vent pipe of hessian can be made as follows, using spot-welded steel mesh (4 mm bars at 100 mm centres) A sheet of mesh 2 5 m long and 0.8 m wide is rolled into a tube to give an internal diameter of about 25 cm Hessian or jute fabric (sacking) is then tightly stitched around the outside of the tube, and the fly screen fixed at one end by stitching with string or thin galvanized wire Cement mortar (1 part cement, 2 parts sand) is then applied by brush to the hessian surface in thin layers, to a final thickness of at least 1 cm The vent pipe is then ready to be fixed in position

Soil dug from an ant hill can also be used to make a vent pipe Knead the soil well and roll it into "sausages" approximately 10 cm in diameter and 90 cm long Then bend the sausages into rings of about 28 cm internal diameter The vent pipe is built up in *in situ* by laying these rings one on top of the other Vertical reinforcement with short lengths of reed or thin bamboo (or other suitable material) can be driven in through adjacent circles as construction proceeds. When the vent pipe has been built to a height of 2.5 m, its outside surface is smoothed off by adding more soil. The fly screen is attached over the upper end and then a thin coat of cement mortar (1 part cement, 6 parts sand) is applied

High water table

A high water table need not prevent a VIP latrine from functioning efficiently. But if the water table is less than 300 mm deep, the floor of the latrine should be at least 300 mm above ground level

However, the vent pipe is not so effective against the *Culex quinquefasciatus* mosquitoes which breed in the flooded pits of latrines The mosquitoes are less attracted by the light because they emerge at dusk and seem more able to find alternate escape routes via the squatting slab or any small opening. An additional device, effective against flies and mosquitoes, is a fly trap (Figure 18) placed over the drop hole instead of a cover It may also be used on unventilated latrines. Ants will soon discover the trap and help to remove the dead flies Of course, a trap like this must be regularly replaced and well maintained if it is to be effective

Another approach, needing less regular attention from the users, is to pour expanded polystyrene beads into the pit so that they spread out to form a floating layer, through which female mosquitoes cannot lay their eggs and mosquito larvae cannot breathe These beads are often used as packing material and are very cheap They are bulky to transport, but can be obtained from the manufacturers in pellet form and expanded by boiling them in water Experience has shown that the layer will remain in place for over four years; when solid matter falls into the pit, the beads simply move aside and then close over it. The method has been used successfully in Tanzania, India and Belize, using 4-5 mm diameter beads, but it has since been found that 2 mm beads are still more effective The volume of beads to add should be calculated to give a 20 mm thick layer, which is thick enough to be dry on top as a further discouragement to egg-laying mosquitoes.

Twin pit VIP latrines

The VIP principle can also be used on a twin pit latrine. But in that case the partition wall between the pits must have a good foundation and be fully mortared to prevent any cross-flows of air between the pits, which might cause odours to come up through the drop hole For the same reason, a separate vent pipe is needed for each pit and the floor slab should be firmly bedded with mortar on the partition wall as well as on the pit lining or collar.

Multiple compartment VIP latrines

In southern Zimbabwe, where there is a strong preference for separate men's and women's latrines, double compartment VIP latrines

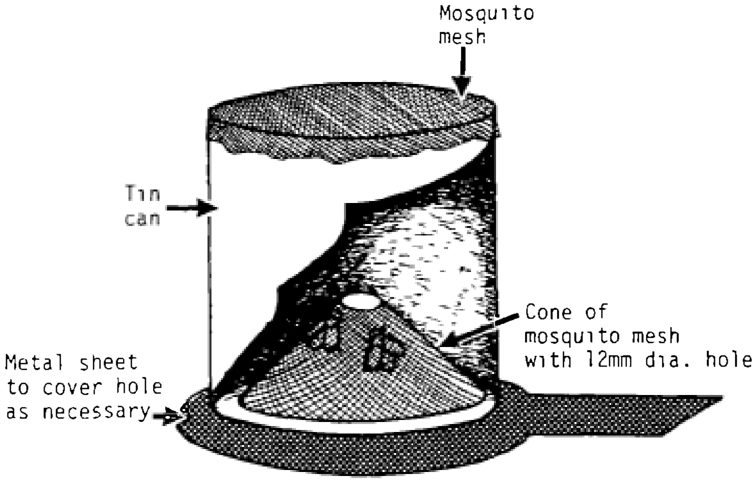


Fig 18 Cutaway view of a simple fly trap which can be made from an old paint tin It is placed over the drop hole of a ventilated or unventilated pit latrine to catch young flies and mosquitoes that try to leave the pit

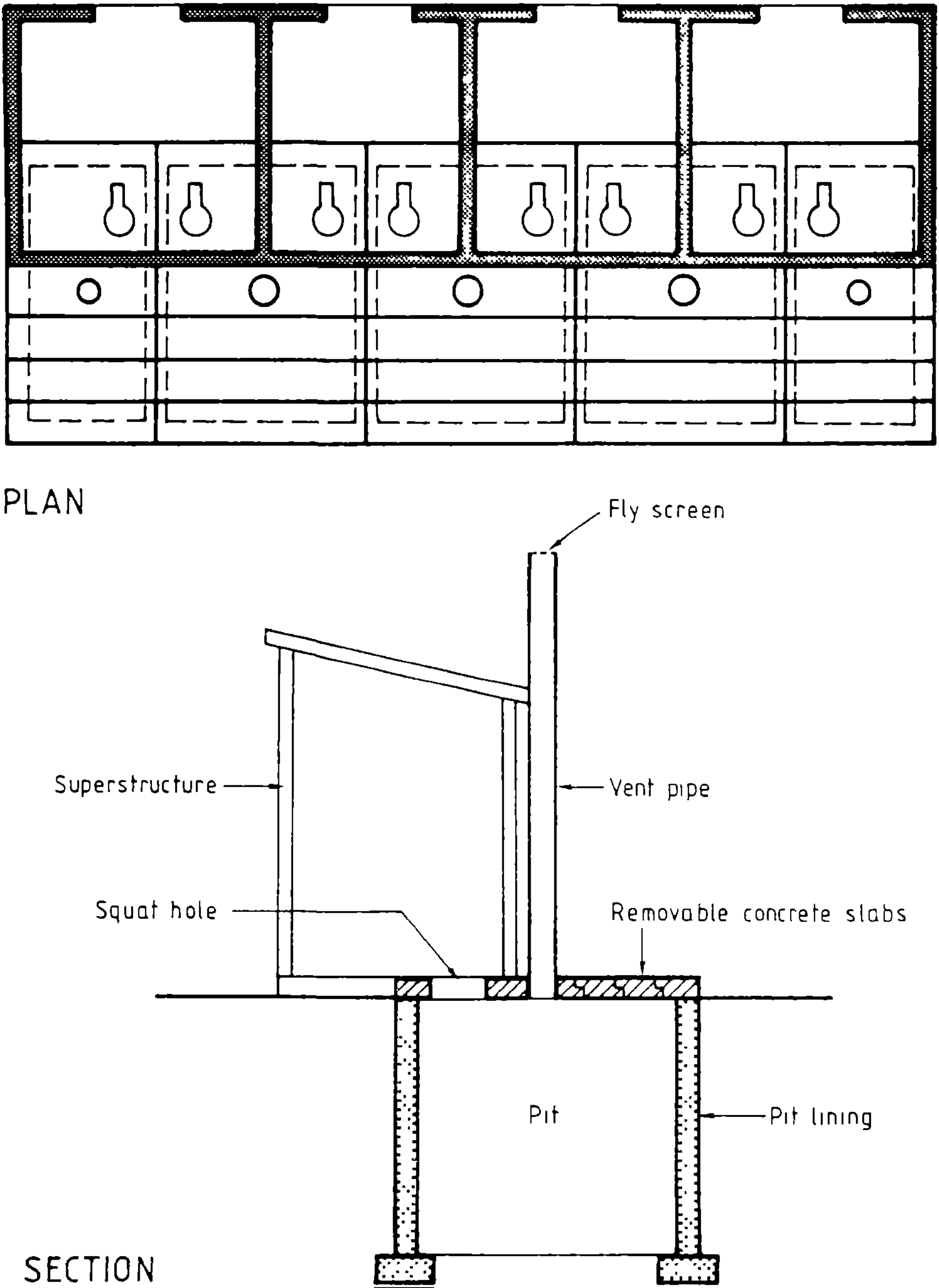


Fig 19 A multicompartment twin pit latrine, as built for schools in Ghana (From Mara, 1984)

have been used. Each compartment may have its own pit, or if a pit lining is needed it will be cheaper to share a common pit with a partition wall as for a twin pit latrine Two or more households may share the latrine, with the men using one compartment and the women the other

Multiple compartment VIP latrines have been developed for schools and institutions. For these also, dividing walls are needed to separate the pits serving different compartments. In Ghana, multicompartment twin pit VIP latrines have been used for schools (Figure 19) Each pit, except the two end ones, serves two drop holes in adjacent compartments

The number of compartments should allow for 10 persons per unit (20 persons per unit in non-residential institutions such as day schools) The number of users per unit can be increased to 30 if soakaways are provided as described below.

VIP latrine with soakaway

This type (Figure 20) has been designed for urban areas where the number of people using a single latrine can be as high as 20 or even, exceptionally, 30. The latrine pit, including its bottom, is completely sealed (with mortar in stable soils or with fully mortared brickwork in unstable soils). A 75 mm diameter PVC pipe with a sanitary tee (a T-shaped pipe) leads from the pit to a soakaway, which is lined with unmortared bricks

This type of pit latrine resembles an aqua-privy, but avoids many of its disadvantages Like an aqua-privy, it needs to be desludged at regular intervals (say, every five years) The vent pipe can be removed to insert a suction hose for desludging The vent pipe is placed directly over the tee so that a rod can be used to clear the tee if it becomes blocked.

This design can be further upgraded by adding a water seal or by connecting the overflow to a small bore sewerage system

4.4 POUR-FLUSH TOILETS

The key to the pour-flush system is the water-seal pan, which must be designed to hold no more than about 1 5 litres of water. This can be achieved by a 20 mm deep, 75 mm diameter water seal (Figure 21). Conventional cistern-flush pans cannot be flushed effectively by hand The bottom of the pan itself should slope by at least 25° so that water poured by hand can move excreta towards the water seal

Suitable lightweight pans made of plastic (PVC, HDP and GRP) are manufactured by various firms particularly in Asia, and can be imported or made locally Pans can also be made of glazed ceramic, mosaic (terazzo finish) or concrete. Concrete pans are often cheapest, but they are heavy, which makes transport less easy, the lack of a shiny-smooth finish means that more water is needed to flush them, and they tend to become stained and smelly with use

Pour-flush toilets can be built indoors, and not only on the ground floor of the house Further details of floor and superstructure construction can be the same as for pit latrines (see Section 4 1).

Soakaway pits

As in the case of VIP latrines, probably the better long-term solution is for pour-flush toilets to have two pits which are used alternately (Figure 22) although this depends on the ease with which the pits can be desludged, whether desludging is to be done by hand or mechanically, and whether in high-density areas there is sufficient room for two pits If desludging is to be done by hand, then twin pits, each with a life of two to three years, are preferable to protect the health of the person carrying out the work One year after switching to a new pit, the humus from the old pit is safe for removal and use as fertilizer.

A suitable rule for choosing the size of each pit is to allow 0.7 m^3 of volume below the level of the inlet for every 5 regular users. This allows sufficient capacity for two years' accumulation of sludge, while still allowing enough freeboard at the sides of the pit for liquids to soak into the soil Widespread experience in India, including pits in relatively impermeable soils, has shown that this is sufficient to absorb all likely amounts of urine and flushing water, except when the pit is dug below the water table so that it is permanently

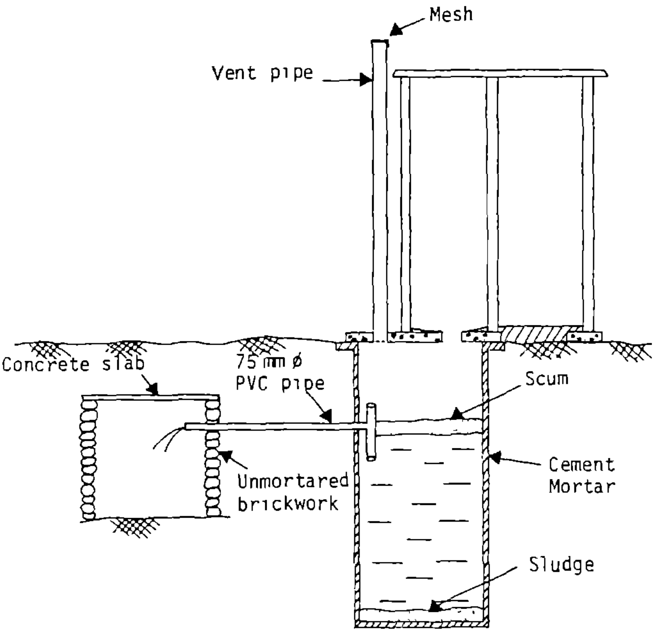


Fig 20 Schematic diagram of a VIP latrine with soakaway (From a drawing by P Morgan)

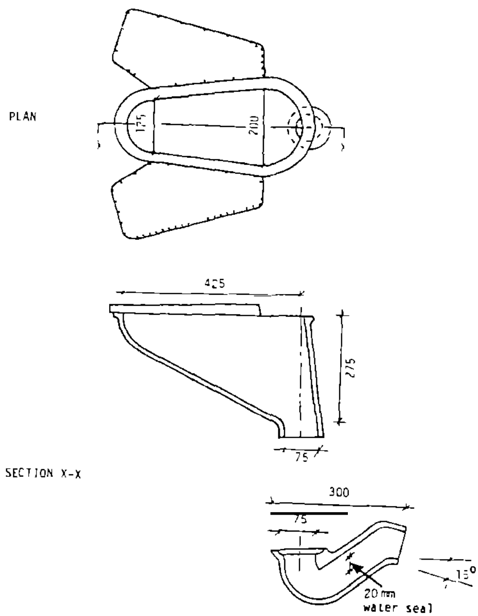


Fig 21 Pour-flush squatting pan and water seal, the Indian standard design (dimensions are in mm) (From Roy *et al*)

flooded. In that case, the pit volume should be doubled Suitable pit sizes based on these rules are given in Table 7.

The soakaway of a pour-flush toilet is not normally designed to absorb all household waste water Pouring large quantities of sullage down the toilet may overload it.

TABLE 7 **Suitable dimensions for pour-flush toilet soakaway pits (metres)**

Number of users (*Dry pit*)	(*Wet pit*)	*Diameter*	*Depth below inlet*
5	3	0.9	1.1
10	5	1.1	1.4
15	8	1.25	1.6
20	10	1.4	1.8

A soakaway pit should be lined, but the lining should allow the movement of liquids through it into the soil. Linings suitable for latrine pits (see Section 4.1) can also be used for the soakaway pits. The type most commonly used for pour-flush toilets is honeycomb brickwork, in which a half-brick space is left between adjacent bricks in each layer of brickwork Perforated concrete rings and bitumen-coated bamboo matting have also been used, although the latter has a limited lifetime. Above the level of the inlet, the lining should be watertight

Pit location
The pits can be located at the back, sides or even in front of the latrine They should preferably be within the house grounds, but if space does not allow this they can be under a path or road outside Of course, they will then need stronger covers to withstand loads from vehicles The distance between the two pits should be no less than their effective depth (measured from the inlet to the bottom of the pit) So as not to undermine the foundations of any adjacent buildings, the distance from any pit to the nearest wall should be at least half its total depth.

In addition, the same precautions with regard to groundwater contamination and natural drainage lines should be taken in locating soakage pits, as described for pit latrines.

Where the water table is so high that the pit itself is waterlogged, it is advisable to raise the top of the pit above ground level as shown in Figure 22(b). The sealed pit bottom and the sand filling around the pit are to limit the spread of ground water pollution

Connecting drain
The pan is connected to the soakaway pits by a 75 mm diameter pipe or a covered brick drainage channel 75 mm wide. This should slope by at least 1 in 30, and preferably be not longer than 3 m, with a maximum of 15 m. If a brick drain is used, it should have a carefully smoothed semi-circular cement bottom Where the drain forks into two branches, one to each pit, it is best to build a small junction chamber (Figure 23) Only one branch is used at a time, the other being closed off by a brick placed in the chamber or in the drain itself and carefully sealed in place with mud or weak

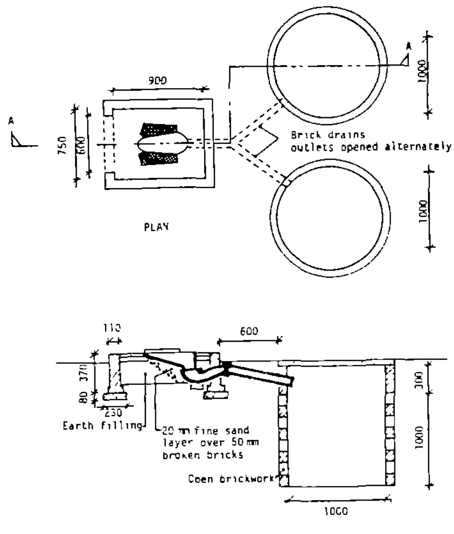


Fig 22 Twin pit pour-flush toilet as built in urban sanitation programmes in India
(a) Normal version

cement When a pit is full, the cover of the junction chamber is removed, and the brick placed in the other branch of the drain.

Where the pipe or drain enters each pit it should project 100 mm, to ensure that the inflow does not run down one wall of the pit and block it.

4.5 SEPTIC TANKS WITH SOAKAWAYS

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 sludge, while lighter solids and grease float forming a thick scum (Figure 24). The solids will decompose, which greatly reduces their volume. Septic tanks need to be cleaned out ('desludged') every 1-4 years to remove heavy accumulations of sludge. Too much accumulated sludge, together with thick scum, will reduce the volume of liquid in the tank, thus 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, which will lead to the clogging of the soakaway. The effluent coming out of 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.

In order to permit effective settling of the solids to take place, a liquid retention time of at least 1 day has been found necessary 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 However, a tank serving many households can be somewhat smaller than this would imply (see Mara and Sinnatamby, 1986).

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 slopes down 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.

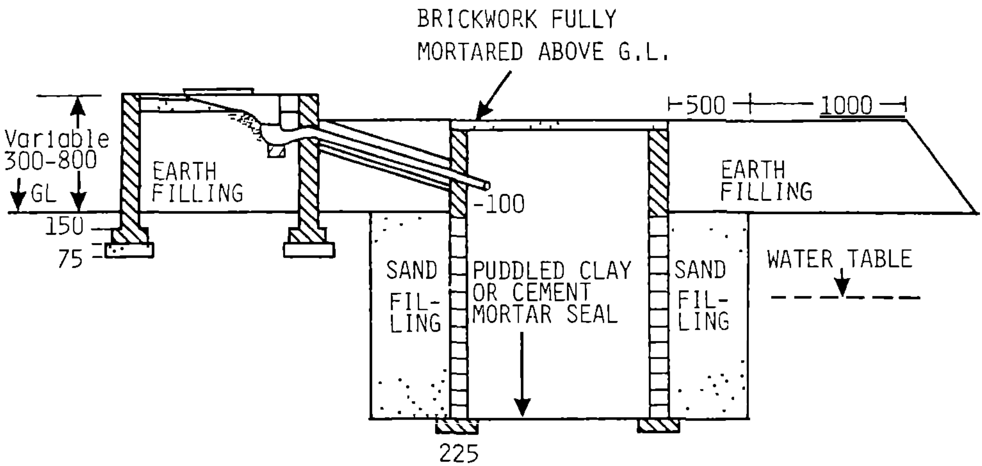


Fig 22(b) Adapted version for waterlogged areas (From Roy *et al*)

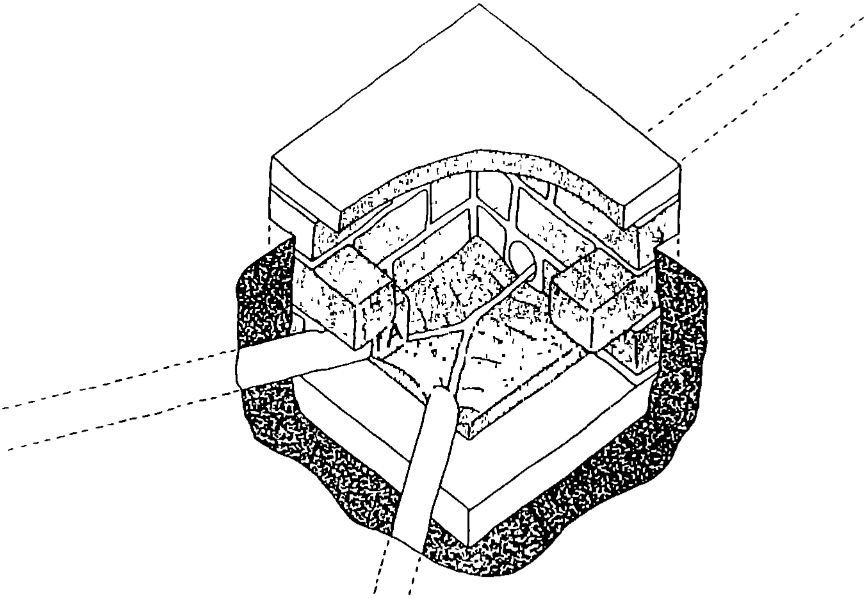


Fig 23 Y-shaped junction chamber for a twin pit pour-flush latrine Note the brick A used to close off the drain to one of the pits (From Mara, 1985)

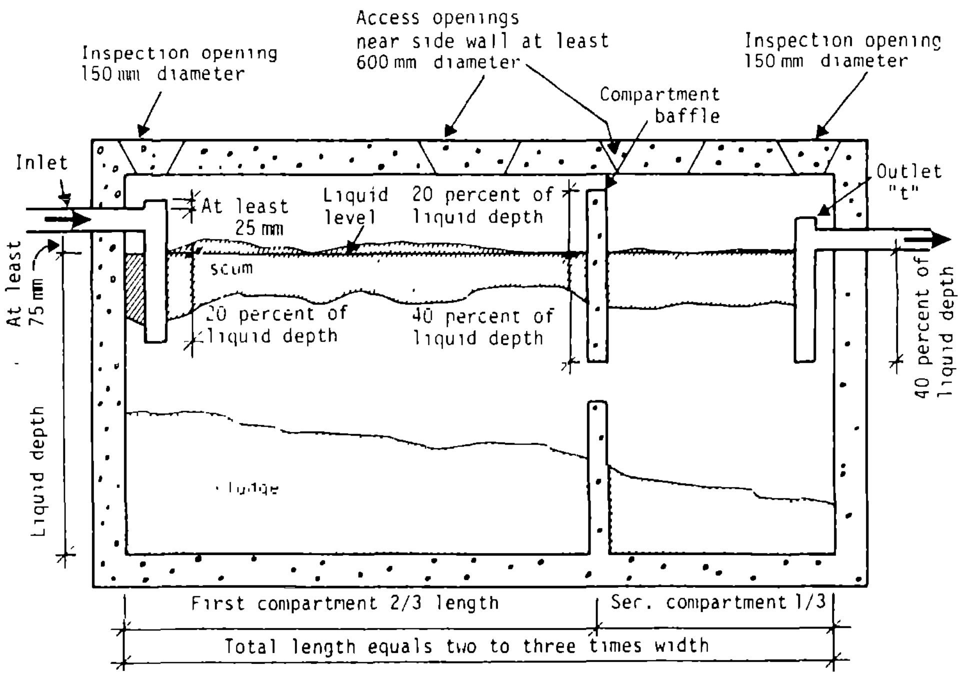


Fig 24 A two-compartment septic tank (After Kalbermatten *et al*)

The operation of a septic tank will be severely hindered if strong disinfectants or alkalis, or large volumes of 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 drinking water, or to trees whose growing roots may damage them Table 8 gives guidelines for location in the form of minimum distances from various features.

TABLE 8· **Distance requirements for septic tanks and soakaways**

Minimum distance from	*Septic tanks (m)*	*Soakaways (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

Source Cotterall and Norris (1969)

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 pit, and a set of soakaway trenches (also known as a drainfield or tile field).

In a soakaway pit (Figure 25), the upper 300 mm of the walls are made watertight, and the cover slab can be buried to keep out insects Soakaway pits are commonly 2-5 m deep, and 1-2.5 m in diameter A pit receiving the effluent from a 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. It will eventually fill up as the surrounding soil becomes clogged, and it may have to be replaced by digging a new pit every 6-10 years. Soakaway pits should not be built within 30 m of a well or other water source, or nearby and uphill from one (see Table 8), and they are not appropriate in 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

In less permeable soils, care should be taken to avoid smearing the sides while excavating the pit, as this can reduce their permeability. The sides of the pit should be scored with the edge of a spade as the lining is built, to improve their infiltration capacity. It will also help to place a layer of fine gravel or sand between the lining and the sides of the pit.

If the area required for infiltration implies an uneconomically large pit, soakaway trenches may be used instead These are filled-in trenches containing open-jointed pipes of

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 is designed as above. So, for a waste flow of 0.1 m^3 per head per day (100 l per head per day), the interval would be 25×0.1 years, that is, the tank should be desludged every 2.5 years.

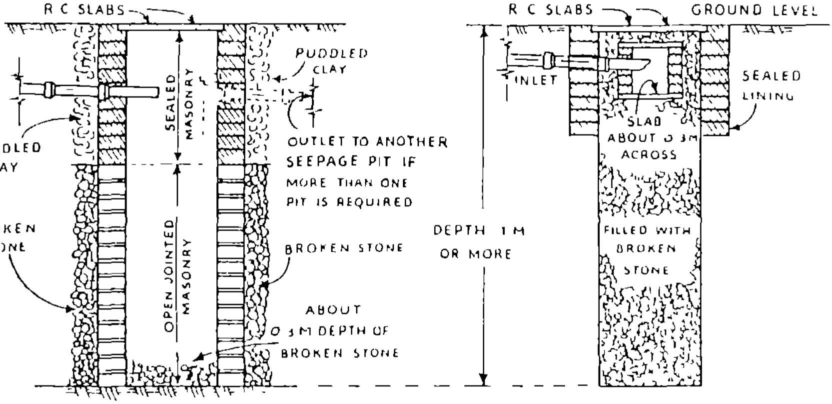
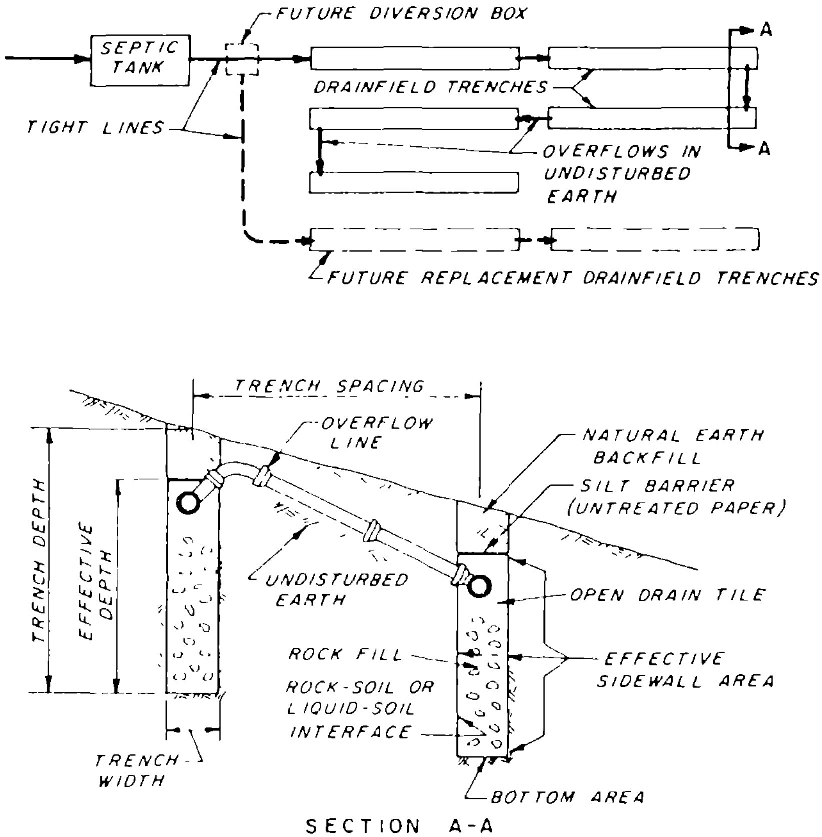


Fig 25 Two kinds of soakaway pit The diameter depends on the infiltration capacity required



100 mm diameter, laid on rock fill, gravel, or broken bricks They provide a larger infiltration area for a smaller volume of excavation than a pit. They should be deep and narrow to obtain the greatest possible side-wall infiltration area.

Normally several trenches are dug, each about 15-30 m long, and connected together to make a drainfield. The trenches should not operate in parallel through distribution boxes, but in series as shown in Figure 26 so that as each trench fills, it overflows to the next one. This ensures that each trench is used either fully or not at all, avoiding the formation of an impermeable crust on the sides.

The minimum spacing between trenches should be 2 m or twice the trench depth, whichever is greater, and each trench should be level with, or below the ones before it. Normally each trench is about 0.3-0 5 m wide, and with depth up to 1 m below the level of the pipe (this is the *effective depth*). An equal area of land should be kept in reserve for possible extension or replacement of the drainfield if it becomes clogged in the future

From the infiltration capacity of the soil (Section 3 4), and the volume of liquid to be infiltrated it is possible to estimate the surface area required on the sides of a pit or soakaway trench below the highest permissible water level The base of the pit or trench cannot be counted as infiltration area, because it is rapidly blocked by sludge.

The trench bottom and the pipes in each trench should be laid as level as possible The pipelaying will be easier if, before starting to fill the trench, tall stakes are driven into the trench bottom and cut so their tops are at the intended level of the pipes. A plank nailed to these stakes, running along the trench on its edge, will then serve as a guideline. It is possible to check that the plank lies level using a hose or plastic tube full of water, lying along the botton 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 with 20-50 mm size stones up to the level of the pipes

Design of soakaway trenches

(i) *Method*

The total length of trench required is calculated from the equation

$$L = \frac{NQ}{2\ DI}$$

where L = trench length in metres,
N = number of users;
Q = wastewater flow in litres per person per day,
D = effective depth in metres;
I = infiltration rate in litres/sq m day (Section 3 4)

(The factor 2 is introduced because the trench has two sides)

(ii) *Example*

Suppose we have a septic tank serving 30 people (N = 30), each using 100 litres/day (Q = 100) The soakaway trenches will be 1 1 m deep, with the pipe buried at 0 3 m depth (D = 1 1 − 0 3 = 0 8) The trenches are to be dug in a silty loam soil (From Table 6, I = 30)

Then

$$L = \frac{30 \times 100}{2 \times 0\ 8 \times 30} = 63\,\text{m}$$

This can be achieved with 3 trenches, each 21 m long, connected in series

Plain-ended clay pipes, or bell-and-spigot sewer pipes, may be used Agricultural drainage pipes, with holes along one side, are ideal if they are available. 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. Once the pipes are laid, they are covered with more stones, then a protective layer of straw or untreated building paper, and finally by 300-500 mm of soil dug from the trench during excavation.

Soakaway trenches cannot be dug where the soil is less than 1.5 m deep, and the level of the ground water table should not rise above the trench bottom Where the water table is high, where there is risk of ground water contamination affecting sources of drinking water, or where the soil is impermeable or difficult to excavate, a possible solution is the soakaway mound (Figure 27). This ensures a greater depth and dispersion of the effluent's travel into the soil It also removes some of the effluent water by evapotranspiration from the grass planted on the top; typically, about 5 litres per day for every square metre of mound surface area. However, these mounds require very large amounts of earth for their construction.

4.6 SEWERAGE SYSTEMS

The task of designing and building a sewerage system is not simple. If possible, a qualified sanitary engineer should be involved in the design work and skilled workers in the construction. The technical factors and design rules involved are too complex to be summarised here, and can be found in other manuals. We recommend Otis and Mara (1985) on small bore sewer systems, and Okun and Ponghis (1975) on conventional sewerage. However, the engineer should be aware of recent developments (UNHCS, 1986) which make it possible to reduce the cost of sewerage by as much as 50%.

Sewers do not dispose of wastes, but only transport them to a suitable place for treatment and disposal Relatively small amounts of sewage can be disposed of by a soakaway (see above), but for larger quantities some form of sewage treatment is usually needed.

Sewage treatment

Various systems for sewage treatment have been developed in temperate countries, but most of them are not appropriate for small communities in tropical developing countries, for two main reasons.

First, most sewage treatment systems are designed to treat the sewage in such a way that it will not harm fish and vegetation in the

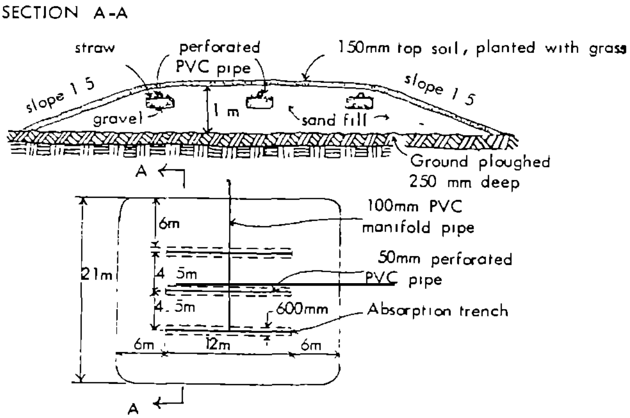


Fig 27 A prototype design for a soakaway mound, for use in areas where the water table or rock is near the surface (From Bouma *et al*)

streams into which it flows. However, this does not necessarily kill or remove pathogens in the sewage. In developing countries, surface streams are often used for drinking water by people living close by, so that sewage discharged into such streams should as far as possible be free from pathogens. Second, most sewage treatment systems involve machinery with moving parts which often has to be imported, and needs regular maintenance.

The only method which is generally appropriate to the treatment of water-borne wastes on the small scale described in this booklet is the waste stabilization pond Ponds are a natural and simple method of oxidising organic wastes and killing or removing pathogenic micro-organisms. They require no machinery, and they are easy to maintain and operate In fact their maintenance is more akin to gardening than engineering. Their efficiency increases with temperature, so they are particularly well suited to tropical climates

Ponds can receive sewage from a conventional or shallow sewerage system, or settled sewage (effluent) from septic tanks via small bore sewers, or nightsoil which is carted to them

For a small system, three or four ponds connected in series are appropriate The first pond would be a 'facultative' pond, while the subsequent ponds would be 'maturation' ponds, which greatly reduce the numbers of pathogens in the sewage (Figure 28). The wastes flow by gravity from one pond to the next.

Detailed information on ponds is given by Mara (1976), but the essential factors are summarised below.

Facultative ponds

The facultative pond is the main work horse of a pond system and is the first pond into which the wastes flow In the upper layers of the pond, oxidation of organic matter takes place using oxygen provided by algae At the bottom of the pond, sludge accumulates and is decomposed by anaerobic bacteria.

To design a facultative pond it is simply necessary to calculate its area and its depth. Depth is chosen as 1 5 m, a compromise between low efficiency in deeper ponds and the risk of vegetation such as reeds emerging from ponds which are too shallow. The area can be calculated from a number of formulae The method on page 52 is adequate in most cases

Nightsoil may also be treated in a facultative pond by dumping it on a concrete ramp and sluicing it down into the pond with a jet of water The water level in nightsoil ponds tends to fall due to evaporation so that water must be added to keep them full. This can be done by channelling through them some of the flow from an adjacent river or stream

Maturation ponds

A facultative pond receiving sewage must always be followed by two or more maturation ponds Maturation ponds are responsible for the final improvement in quality and for the reduction in the numbers of pathogenic bacteria and viruses Although sophisticated design methods are available (see page 54), a good rule of thumb is to choose 2 maturation ponds, each with a retention time of 7 days and a depth of 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 similar total area) will provide an effluent of substantially better microbiological quality

Fig 28 Sequence of ponds in a small stabilization pond system F = Facultative pond, M = Maturation pond (After Mara, 1977)

Design features

Stabilisation 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 roughly rectangular with a breadth to length ratio of 1 to 2 or 1 to 3. The bottom of a pond should be impermeable. The sludge deposited in the pond can seal up small pores in the soil. But if the soil is coarse,

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Design procedure for a facultative pond

(i) *Method*

Calculate the area from

$$A = \frac{LQ}{1.5T-5}$$

where
- A = pond area (m^2)
- L = strength of the raw sewage to be treated (this is measured in mg/l of 5-day biochemical oxygen demand, known as BOD)
- Q = total flow of sewage (m^3/day)
  = water use per person per day × population
- T = the average temperature of the coldest month (°C)

T can be found from meteorological records, available either from the Government meteorological department or from an airport.

L may be ascertained by asking a local engineer what strength of sewage he has found in your area.

An alternative formula, which may be easier to use, is the following:

$$A = \frac{PB}{1.5T-5}$$

where
- P = population to be served
- B = amount of BOD produced (g/person . day)

and A and T have the same meanings as before.

A reasonable estimate for B is 40 g/person day. If the sewage has passed through a septic tank or aqua privy before reaching the pond, or if only nightsoil is to be treated, then a value of 20 g/person day can be used.

The area derived from these formulae is the mid-depth area, related to the dimensions of the pond at mid-depth. When these have been chosen to give the required area, the actual length and width of the pond bottom can be derived from them as shown in Figure 29.

(ii) *Example*

Suppose you are designing a pond to receive the septic tank effluent from a community of 2000 people in a part of Northern Nigeria where T = 22°C.

For septic tank effluent, B = 20 g/person day.

$$A = \frac{20 \times 2000}{(1.5 \times 22) - 5} = 1429\,m^2$$

Suitable mid-depth dimensions for this area might be 22×65 m.

with less than 8% clay, 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 drive a herd of sheep or cattle around 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 on the outside, and 1 in 3 on the inside The top should be at least 0 5 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 stabilised soil are appropriate (see Plate 12)

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 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 30.

Stabilisation 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, swimming, etc.

Pond maintenance

Maintenance consists only of preventing vegetation growth, maintaining the fence, keeping the inlets and outlets free from blockage, 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 pond systems serving up to 10,000 people, one labourer *under good supervision*, and perhaps a watchman, 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.

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)

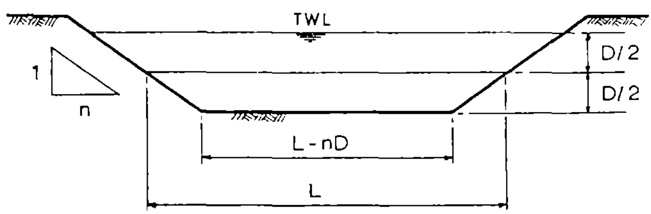

Fig 29 Calculation of dimensions of pond bottom from those derived from mid-depth area (From Mara, 1977)

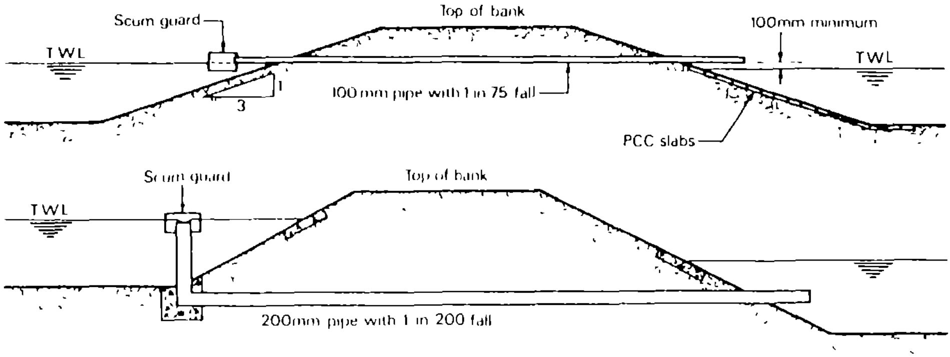

Fig 30 Two examples of simple interpond connections PCC pre-cast concrete (From Mara, 1977)

Bacterial reduction in a set of ponds

(i) *Method*

The concentration of faecal bacteria in sewage is best measured in terms of the number of faecal coliforms (FC) in 100 ml. It has been found in practice that, if

Ni = number of FC/100 ml of influent flowing into a pond

and Ne = number of FC/100 ml of effluent flowing out of a pond

then

$$\frac{Ni}{Ne} = 1 + Kt$$

where t = the retention time of the pond, in days

and K = a factor indicating the rate of bacterial die-off

K is very sensitive to temperature; it increases by nearly 20% for every degree C. The correct value to K to use is the one corresponding to T, the average temperature of the coldest month of the year If T is not less than 20°C (as in most tropical regions) a reasonable value is

$$K = 2.6$$

For a series of, say, 3 ponds, with retention times t_1, t_2 and t_3 the overal ratio is

$$\frac{Ni}{Ne} = (1+Kt_1)(1+Kt_2)(1+Kt_3)$$

(ii) *Example*

Calculate the degree of bacterial reduction in a facultative pond with retention time 15 days followed by three 5-day maturation ponds, if T = 20°C.

$$\frac{Ni}{Ne} = (1+2.6\times 15)(1+2.6\times 5)^3 = 109760 = 10^5 \text{ approx}$$

The value of Ni for raw sewage is not usually greater than 10^8 FC/100 ml

These ponds will therefore produce a treated effluent with Ne not greater than $10^8/10^5 = 10^3$ FC/100 ml. This quality would be good enough for irrigation, even of vegetable crops (but see Section 3.8).

GLOSSARY

algae	microscopic water plants
aquatic	living in water
cistern-flush	flushed by water from a small tank called a cistern.
composting	a method of treating dry wastes (see Gotaas, 1956, for details).
defecation	the deposition of faeces.
desludging	removing accumulated sludge from septic tanks, aqua privies etc.
dysentery	diarrhoea with blood or mucus in the faeces.
effluent	outflowing liquid
excreta	in this Bulletin, 'excreta' refers to both faeces and urine.
extension system	an arrangement to promote communication between planners and the community, usually employing community workers.
ferrocement	cement mortar reinforced with wire mesh
filariasis	a disease caused by a parasitic worm and transmitted by mosquitoes. Its symptoms include elephantiasis, a crippling swelling of the legs.
focus	a place where disease transmission takes place
hand-auger	a device for boring holes by hand, often used to plant fence posts.
helminth	a worm Parasitic worms can live in the body and cause disease.
hookworm	an intestinal parasitic worm 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
host	see 'parasite'.
humus	decomposed organic matter like that found in rich soil
impermeable	watertight; through which water cannot pass.
infiltration	movement of water or sewage into the soil
larva	a stage in the development of worms and insects (plural: larvae).
nightsoil	human excreta, transported without flushing water
parasite	an organism that lives on or in another living organism (called the host) and draws nourishment from it.
pathogen	an organism which causes disease. Most pathogens are microscopic in size.
permeable	allowing water to pass through easily
pour-flush	flushed by a small amount of water poured by hand.
rammed soil	soil which has been compacted by ramming it with a heavy weight
roundworm	an intestinal parasitic worm Its eggs can survive long periods in the environment, and infect man when they are swallowed
seepage	infiltration (see above).
sewage	human wastes and waste water, flushed along a sewer pipe
sewerage	a system of sewer pipes.
shallow sewerage	a low-cost kind of sewerage, in which the pipes are laid at shallower depth and flatter gradient than usual, with smaller diameters and fewer manholes.
sludge	solid material which sinks to the bottom of septic tanks, ponds etc.
small bore sewerage	a low-cost kind of sewerage to collect the effluent from septic tanks.
soakaway	a pit or trench in the ground used for the disposal of liquid wastes.
standpipe	a public tap.
sullage	domestic dirty water not containing excreta.
water table	the level in the ground at which water is found.
yard-tap	the level of water supply at which each household has a single source of water in or near the house, often in the yard.

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IRC	WHO International Reference Centre for Community Water Supply and Sanitation PO Box 93190 2509 AD The Hague The Netherlands
IRCWD.	International Reference Centre for Wastes Disposal Ueberlandstrasse 133 CH-8600 Duebendorf Switzerland
IT Publications.	Intermediate Technology Publications Ltd 103-105 Southampton Row London WC1B 4HH
John Wiley	John Wiley & Sons Baffins Lane Chichester PO19 1UD.
SIDA	Swedish International Development Agency Birger Jarlsgatan 61 S-105 25 Stockholm Sweden
UNCHS	United Nations Centre for Human Settlements (Habitat) PO Box 30030 Nairobi Kenya.
USEPA	U S Environmental Protection Agency Office of Water Program Operations Washington DC 20460 USA
WHO.	World Health Organization 1211 Geneva 27 Switzerland.
World Bank	The World Bank 1818 H Street Washington DC 20433 USA

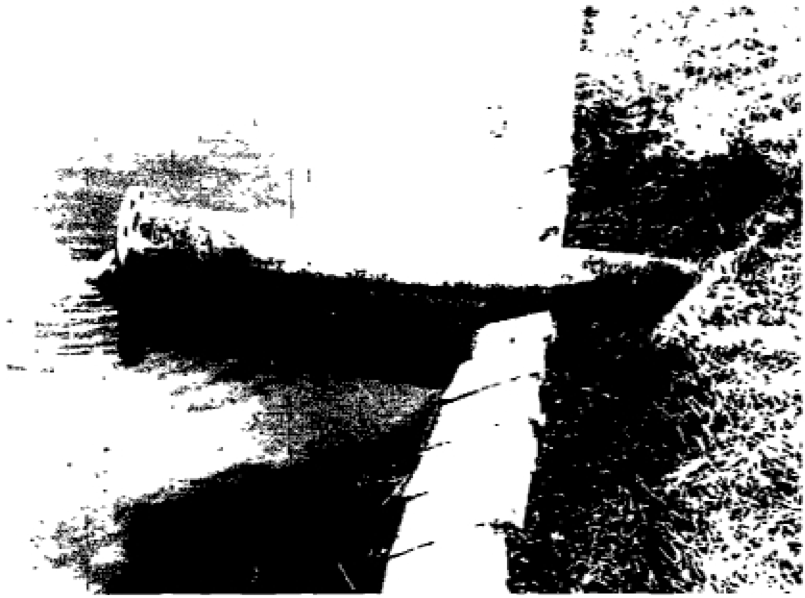
The World Bank has produced an extensive series of free publications on low-cost sanitation It is worth writing for an up-to-date list.

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 conversions 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

Plate 12 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)



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