Sanitation Technology and Related Health Aspects
(An Illustrative Manual)

Compiled by

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Environmental Engineering Division
Asian Institute of Technology
Bangkok, Thailand
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I. Sanitation Technology

1. Introduction:

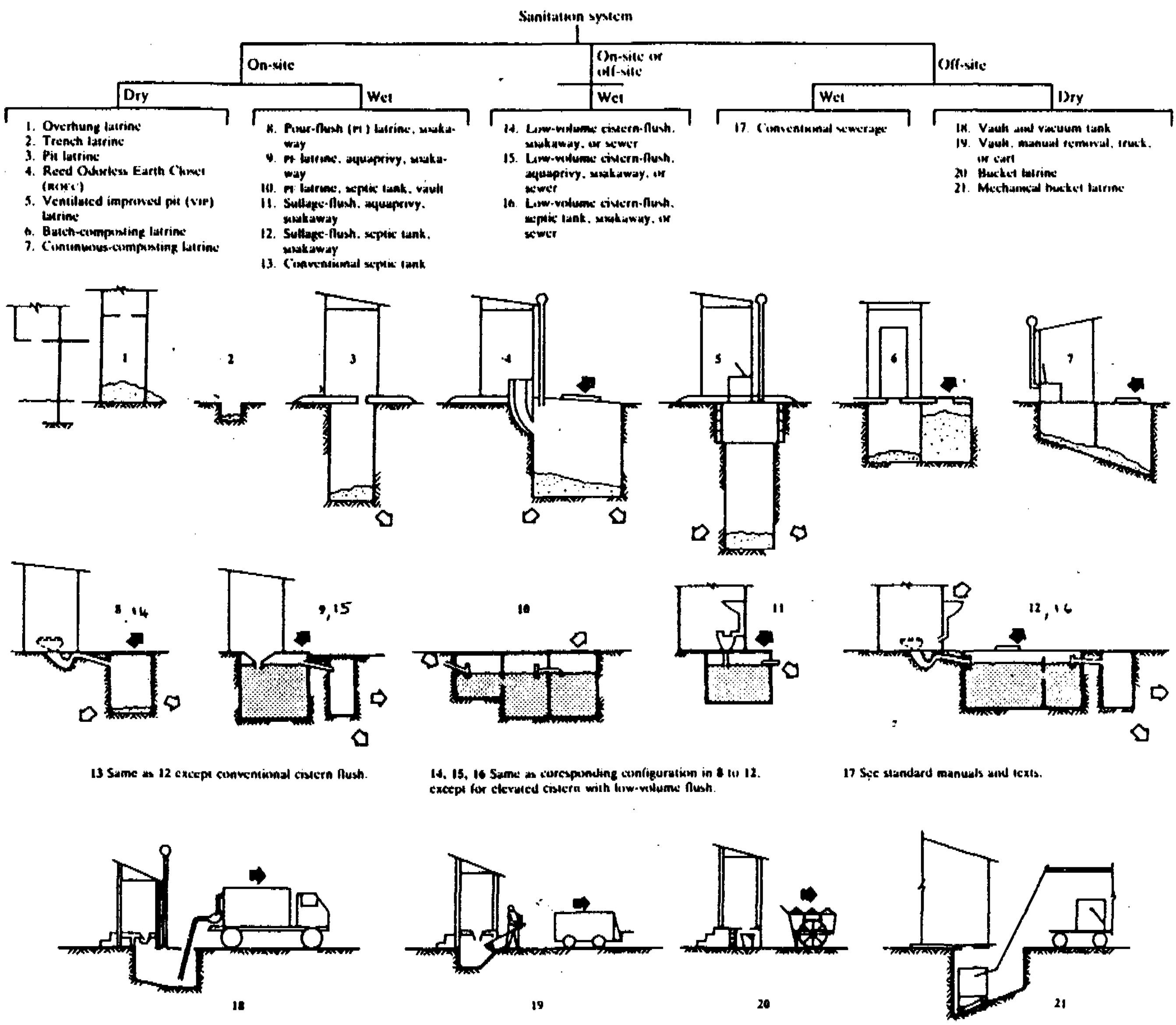
Improved health is normally considered as one of the main benefits of improved sanitation. Excreta contains a wide range of human pathogens, which if not properly treated, can have a dramatic effect on community health. Technologies for excreta treatment, to achieve the proper sanitation, are readily available. A generic classification of these technologies has been presented in Figure 1.

Selection of these technologies mainly depends on the following factors:

- Climatic conditions (temperature ranges, precipitation).
- Site conditions (topography, soil stability, hydrology).
- Population (number, density, housing types, available labour and indigenous raw materials etc).
- Environmental sanitation (existing water supply service levels, marginal cost of water supply improvements, existing facility for excreta treatment etc).
- Cost factor (economical and financial analysis for the proper selection of a sanitation technology).
- Sociocultural factors (hygiene education level, religious or cultural factors affecting hygiene practices & technologies, perception of the present facilities, attitude towards resource reclamation and communal or shared facilities etc.).
- Institutional framework (allocation of responsibility; effectiveness of state, local or municipal institutions in providing water, sewerage, sanitation, drainage, health and education services etc).

Table 1 presents a comparison of different sanitation alternatives which can be used as a guide for the selection of a sanitation technology.

Major on-site/ off-site technologies are described briefly in the following pages.



◊, Movement of liquids; ⧫, movement of solids.
Source: The World Bank. *Water Supply and Waste Disposal*, Poverty and Basic Needs Series (Washington, D.C.: September 1980).

Fig. 1 Generic classification of sanitation systems

Table 1 Comparison between different types of sanitation alternatives

Sanitation technology	Rural application	Urban application	Construction cost	Operating cost	Ease of construction	Self-help data potential	Water requirement	Required soil conditions	Complementary off-site investments	Reuse potential	Health benefits	Institutional requirements
VIP latrines and ROECs	Suitable	Not suitable	Low	Low	Very easy except in wet or rocky ground	High	None	Stable permeable soil; G.W.T. 1 m below surface	Sullage disposal facilities	Low	Good	Low
DVC toilets	Suitable	Not suitable in high density areas	Low	Low	Easy	Medium	None	None (can be built above ground)	Sullage disposal facilities	High	Good	Low
Chinese 3 Stage septic tank	Suitable	Not suitable	Medium	Low	Requires skilled builder	Medium	Water near toilet	None (can be built above ground)	Sullage disposal facilities	High	Moderate	Low
Vault toilets and vacuum trucks	Not suitable	Suitable where vehicle access and maintenance available	Medium	High	Requires skilled builders	High	Water near toilet	None (can be built above ground)	Sullage disposal and off-site treatment facilities	High	Good	Very high
PF toilets	Suitable	Not suitable in high density areas	Low	Low	Requires skilled builder	High	Water near toilet	Stable permeable soil; G.W.T. 1 m below ground surface	Sullage disposal facilities	Low	Very good	Low
Sewered PF toilets	Not suitable	Suitable	High	Medium	Requires skilled engineer	Low	Water piped to house	Preferably stable soil, no rock	Off-site treatment facilities	Low	Excellent	High
Conventional sewerage	Not suitable	Suitable where it can be afforded	Very high	Very high	Requires skilled engineer	Low	Water piped to house and toilet	Preferably stable soil, no rock	Off-site treatment facilities	High	Excellent	High
Septic tanks	Suitable for rural institutions	Suitable in low density suburbs	Very high	Very high	Requires skilled builder	Low	Water piped to house and toilet	Permeable soil; G.W.T. 1 m below ground surface	Off-site treatment facilities	None	Excellent	Low

2. On Site Treatment Technology:

2.1. Latrines and Toilets: The major components of a latrine and / or toilet are:

(a) Superstructures provide privacy, and protect the users and toilets from the weather. The size of a superstructure (plan area) should be 0.8 to 1.5 m^2, with the roof height of 1.8 m and ventilation openings at the top of the walls (75 to 100 mm by 150 to 200 mm in size). Provision of a door for maintaining privacy and for natural light should be available.

Further, the walls and roof should be waterproof. A variety of materials including brick, concrete blocks, corrugated iron, or asbestos-cement roof etc. are available for roofing.

Several low cost and easily constructed superstructures are shown in Figures 2a and 2b.

(b) Fixtures for latrines and toilets are often included in the construction of the pit or other substructures. The base of fixtures may be constructed separately of wood or intregally as part of the squatting plate.

It is essential to determine whether the local preference is to sit or squat during defecation. A short description of squatting plate and/or pedestrial seat used in latrines and toilets are given below:

(i) Squatting plate for VIP latrines: While designing a squatting plate for VIP latrines, the following criteria should be considered.

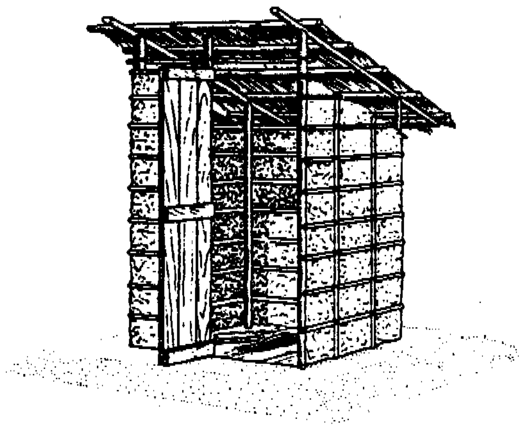
- Opening size about 400 mm long and 200 mm wide with keyhole shape. This is necessary mainly to prevent soiling of the squatting plate.

- Proper location of the footrests such that the footrest should be an intregal part of the squatting plate.

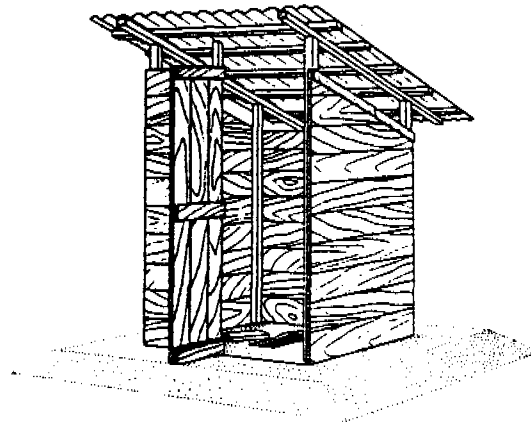
- Distance from the back wall to the opening should be 100 - 200 mm.

- No sharp edge or rough surface of the squatting plate materials.

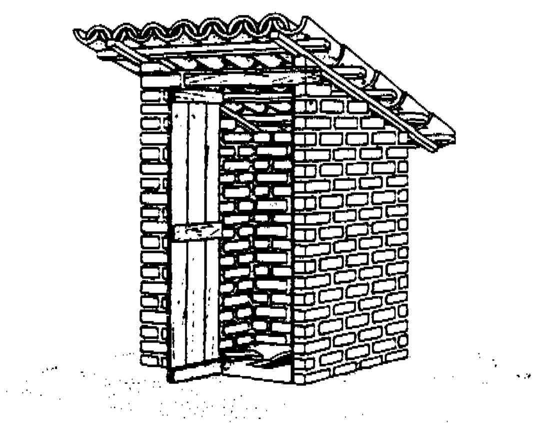
The most common and cheapest materials for the construction of the squatting plate are timber, reinforced-concrete, ferrocement. However, glass-reinforced plastic, high-density moulded rubber, PVC and ceramics are also used.. Figure 3 is an example of the squatting plate which is made of reinforced-concrete. Similarly, Figure 4 is another example of a squatting plate of made of ferro-cement with an intregal metal "Flap-trap" developed in Tanzania.



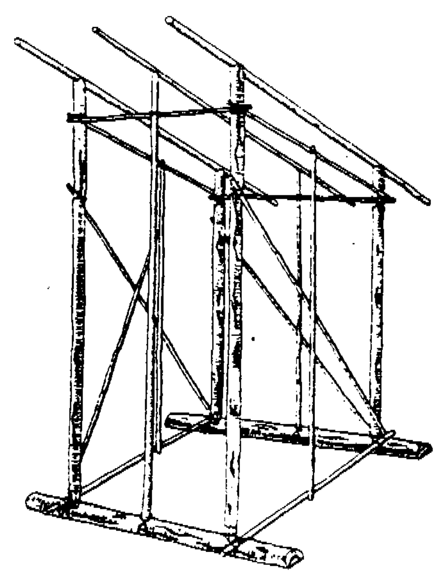
A. Mud and wattle walls and palm-thatch roof



B. Timber walls and corrugated iron or asbestos-cement roof

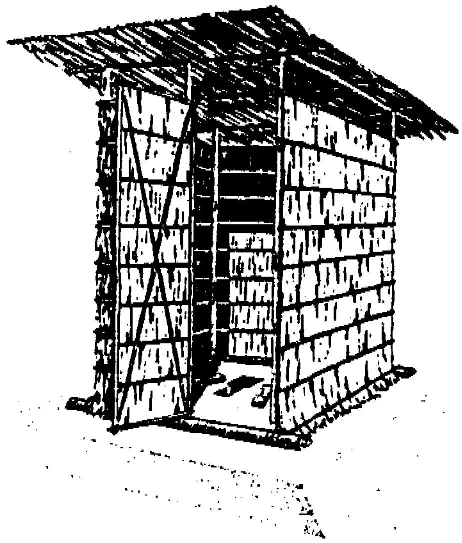


C. Brick walls and tile roof (an alternative is concrete block walls and corrugated iron or asbestos-cement roof)

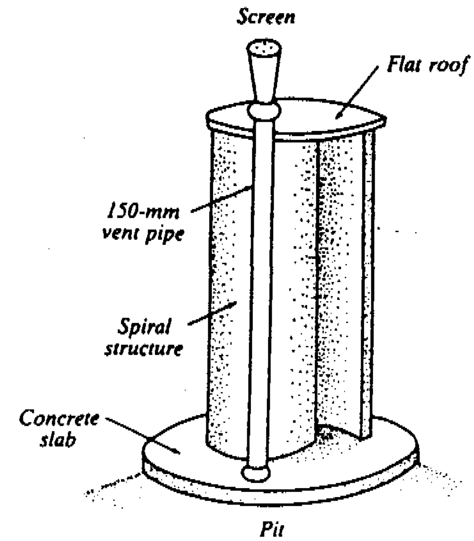


D. Rough-cut tree limbs and logs

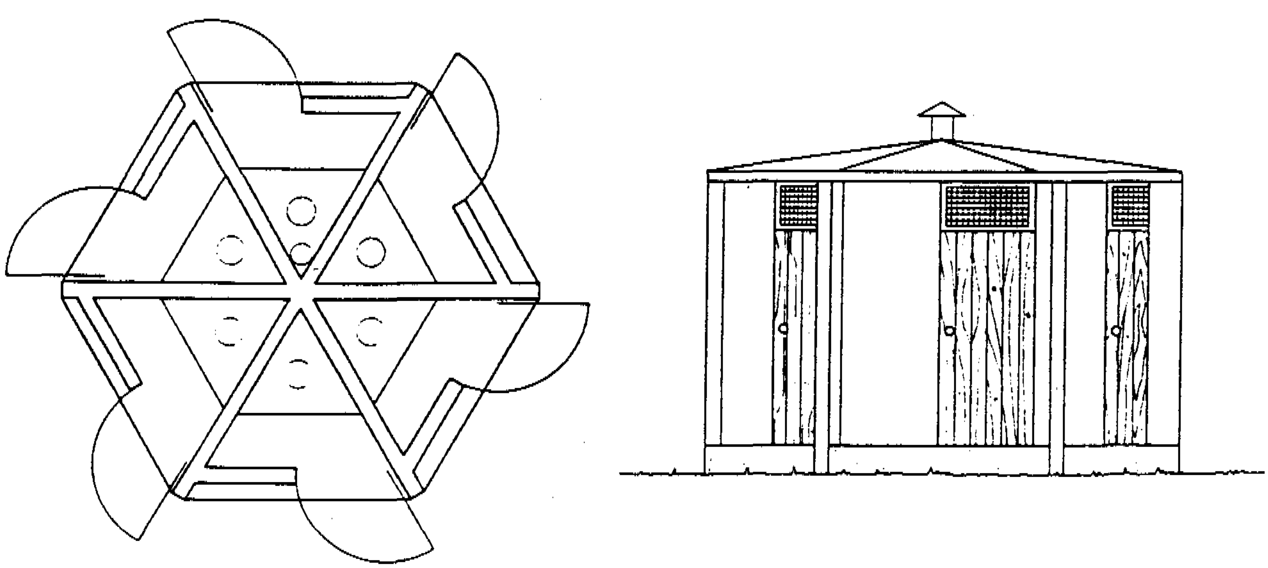
Fig. 2 (a) Different materials for Latrine superstructures



E. Palm-thatch wall and roof covering



F. A ventilated pit privy



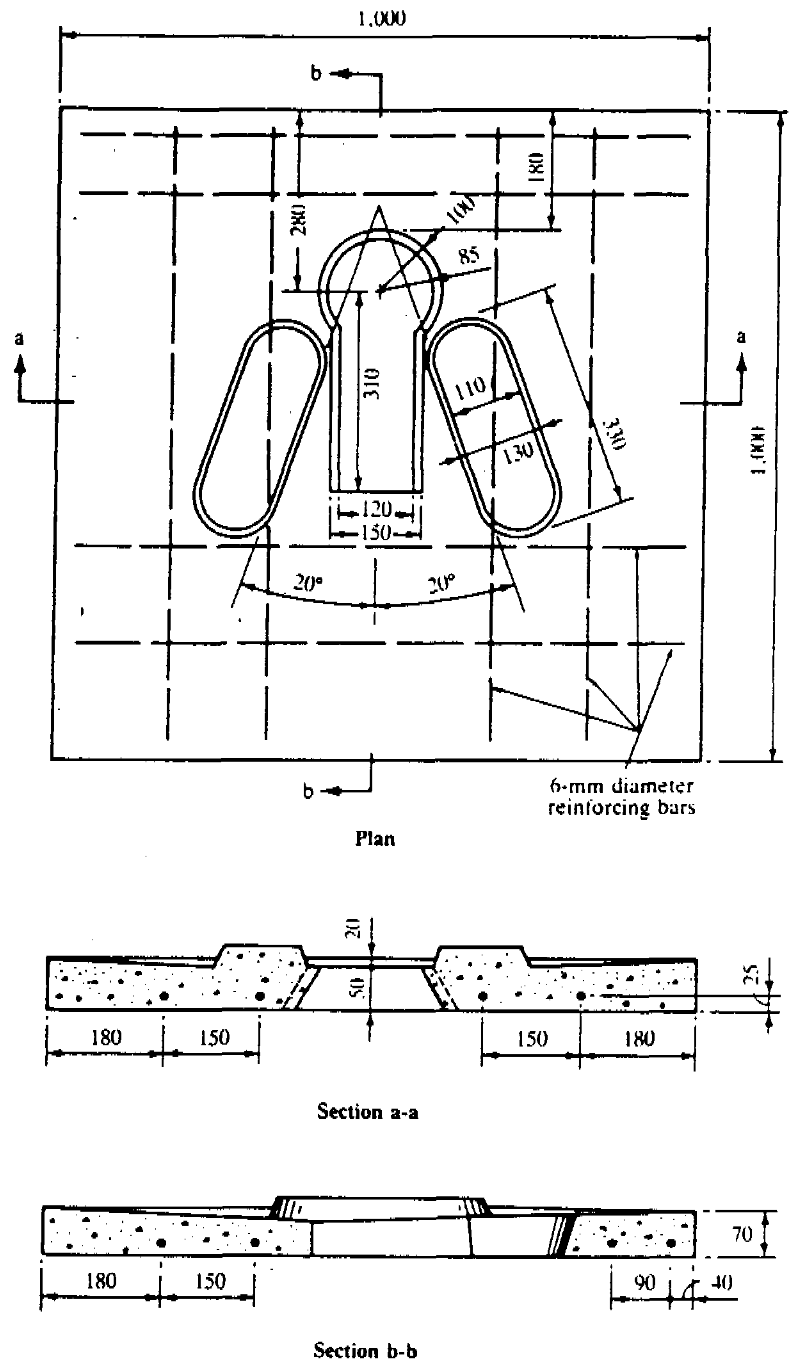
Plan

Elevation

G. Multiple-compartment pit latrine

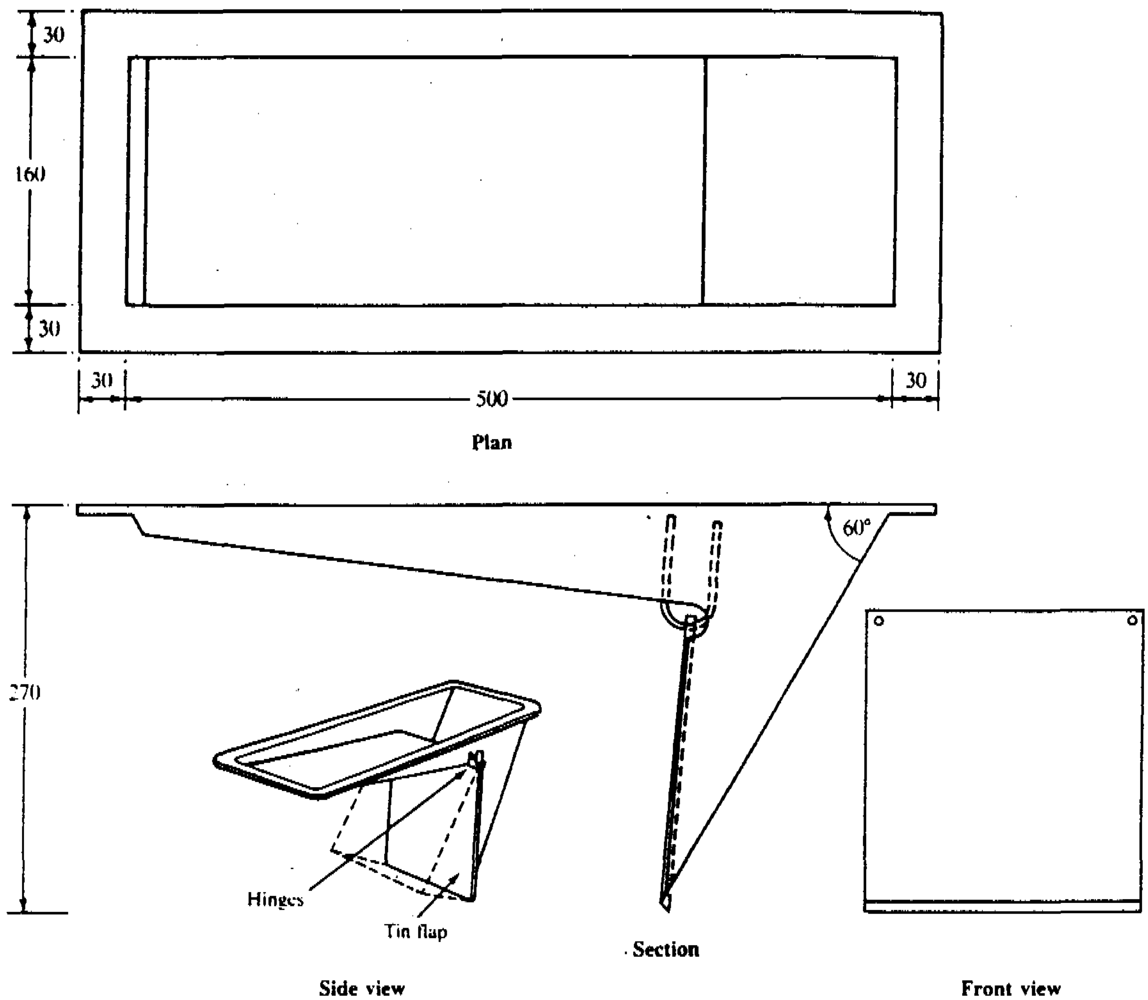
Sources: For A–E, Wagner and Lanoix (1958); for F, *Appropriate Technology* (1979; © International Scholarly Book Services, Inc.; used by permission); G is adapted from a design used in Haiti by the Foundation for Cooperative Housing.

Fig. 2 (b) Different materials for latrine superstructures



Source: Adapted from Wagner and Lanoix (1958).

Fig. 3 Concrete squatting plate (toilet fixtures)



Note: It is suggested that the flap-trap be made of plastic.

Source: Adapted from a drawing by U. Winblad.

Fig. 4 Tanzanian "Flap-trap" design for latrines and DVC Toilets

(ii) Squatting plate for Reed Odourless Earth Closet (ROEC): As shown in Figure 5, a steep (60°) sloping chute (diameter 150-200 mm) is necessary to provide for a ROEC so that excreta can be directed into the adjacent offset pit.

(iii) Pedestral seats for Ventilated Improved Pit (VIP) latrines & ROEC: While designing the pedestal seat, one should consider the height of the seat and opening size. The pedestal riser can be constructed in brick, concrete blockwork, or wood; internal surfaces of a ROEC should be smooth and accessible for cleaning. Figure 5 is an example of the pedestal seat.

(iv) Squatting plates for composting, pour-flush and vault-toilets: Squatting plates for composting toilets are the same as those for VIP latrines, except that, if urine is to be excluded, a suitable urine drainage channel must be provided.

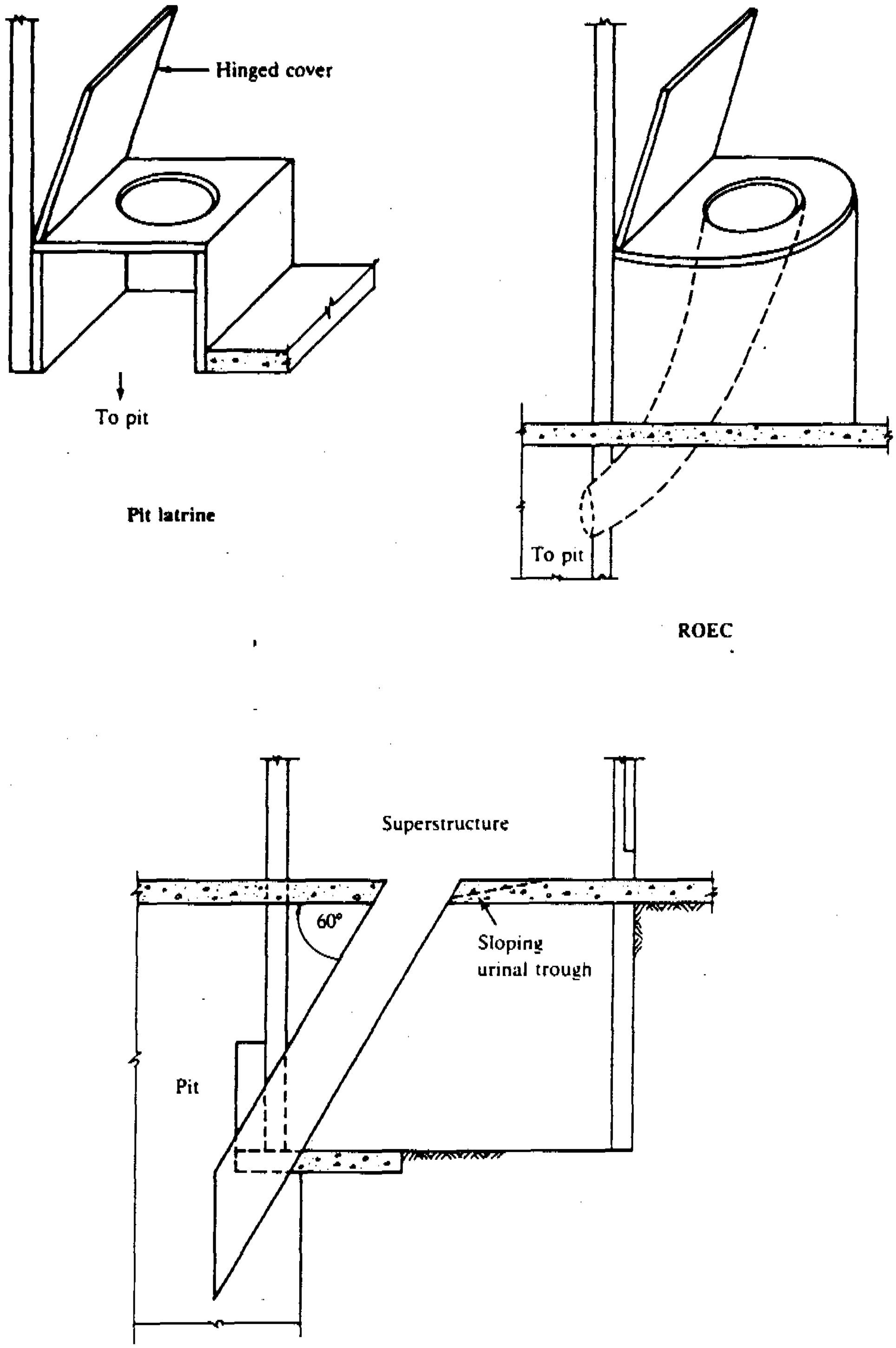
Squatting plates for vault and pour-flush toilets are in Figure 6 where the plate is situated immediately over the pit or vault. This unit is most easily made from ferro-cement or reinforced plastic. Figure 7 is another example of squatting plate for pour-flush which a modification of the Tanzanian `Flap-trap'. This unit is galvanized before it is cast into ferrocement slab. Figure 8 is a similar design that can easily be made from produced in plastic. If the squatting plate is connected to a completely displaced pit or vault, the design is of the type as shown in Figure 9.

2.2. Conventional pit latrines: A pit latrines has three components: a pit, a squatting plate (or seat and riser), and a superstructure. A conventional pit latrine of unimproved type is shown in Figure 10. This type of latrine is usually malodourous, and flies and mosquitoes readily breed in it.

Recent develpoment work in the area of pit latrine has made pit latrines to be odourless, and they have minimal fly and mosquito nuisance. Figure 11 is an example of a conventional improved pit latrine in which ventilation has been provided. Thus it is known as "Ventilated Improved Pit (VIP) latrine". This latrine is hygenic, low-cost, and more acceptable form of sanitation that has only minimal requirements for users' care and municipal involvement.

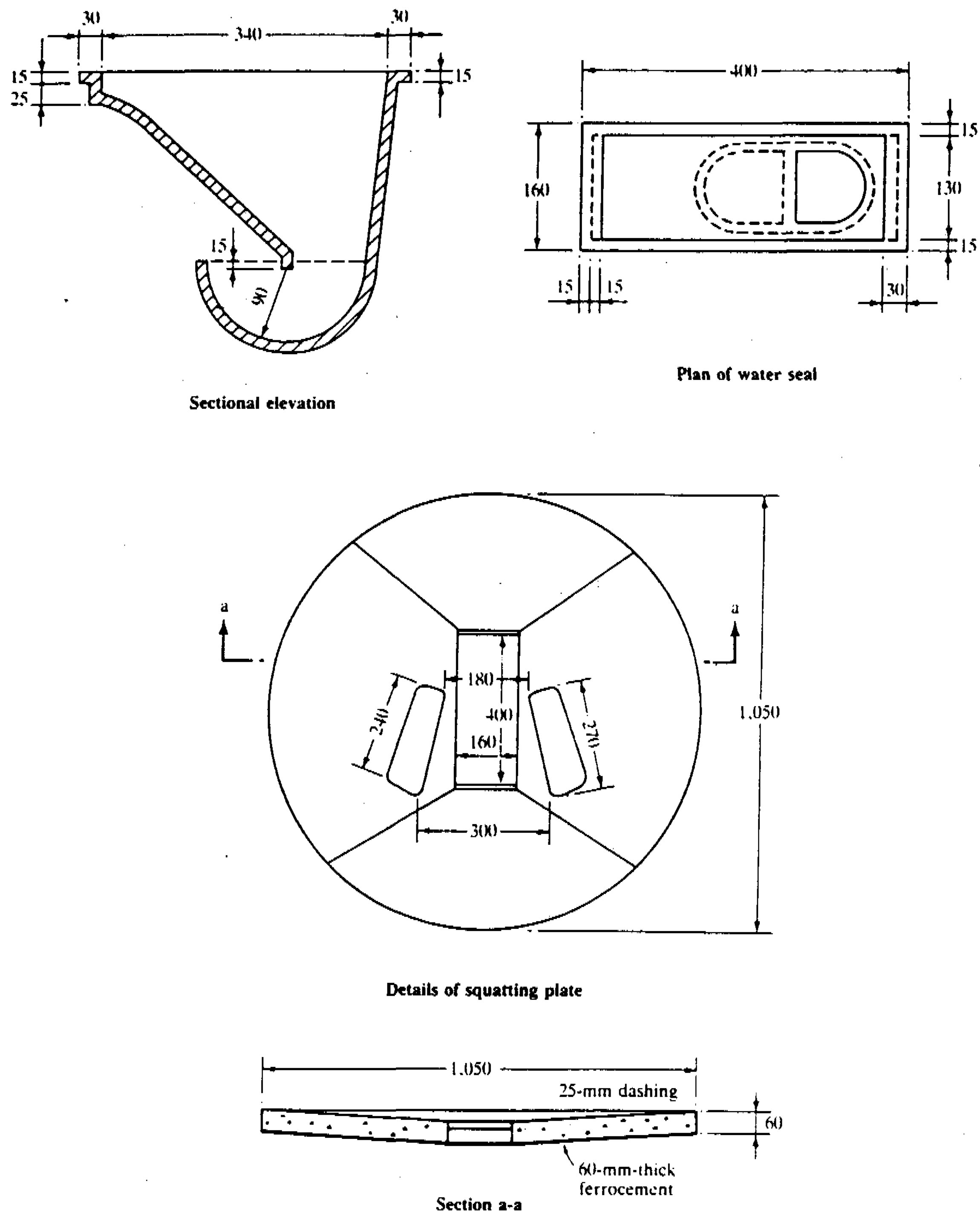
Figure 12 is an example of VIP latrine with two pits, which is often referred to as "Ventilated Improved Double Pit (VIDP) latrine". The advantages of this latrine over VIP latrines are as follows:

- eliminates the need to construct the very deep pit.
- no need to construct another latrine once the pit is full and to facilitate the emptying of the pit where space for a replacement latrine does not exist.



Note: The pedestal hole should be 100 millimeters in diameter for use by children, 200 millimeters for adults. Unsupported fiberglass should not be used in construction.

Fig. 5 Pedestral seats for dry latrines and chute designs for ROEC's



Source: Adapted from Wagner and Lanoix (1958).

Fig. 6 Water-seal squatting plate for PF toilets located immediately above the pit

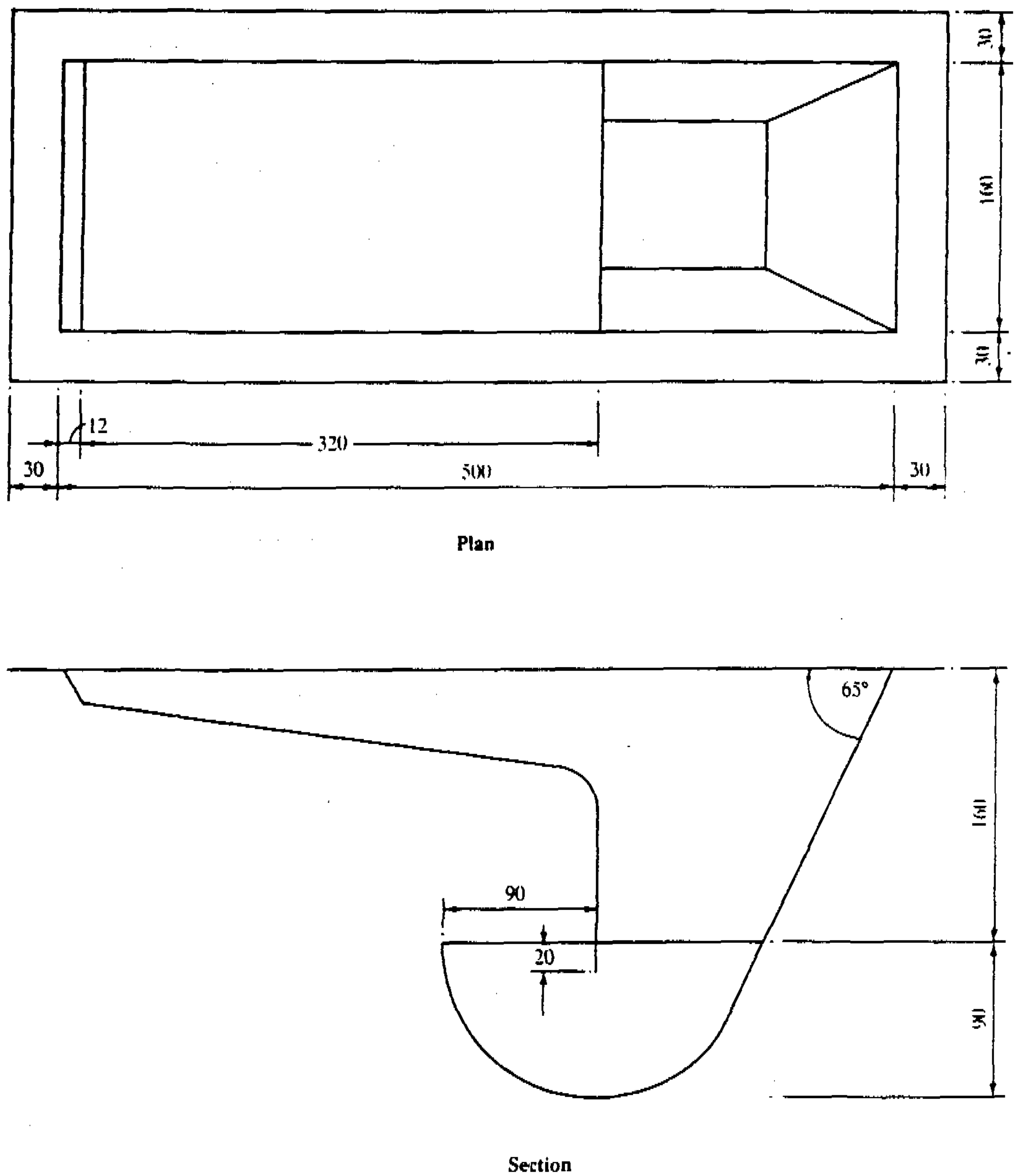
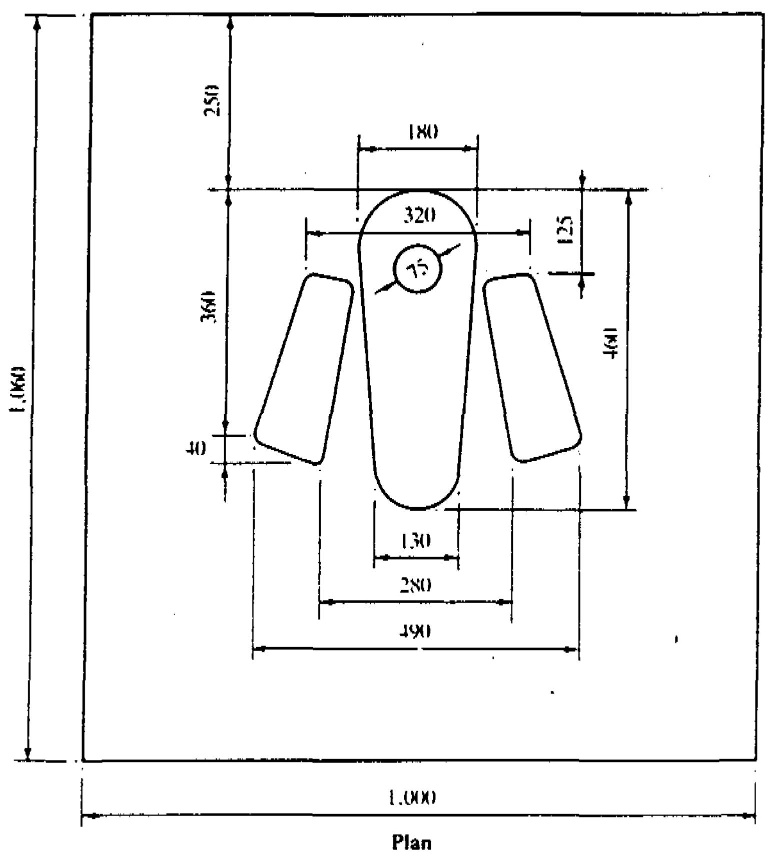
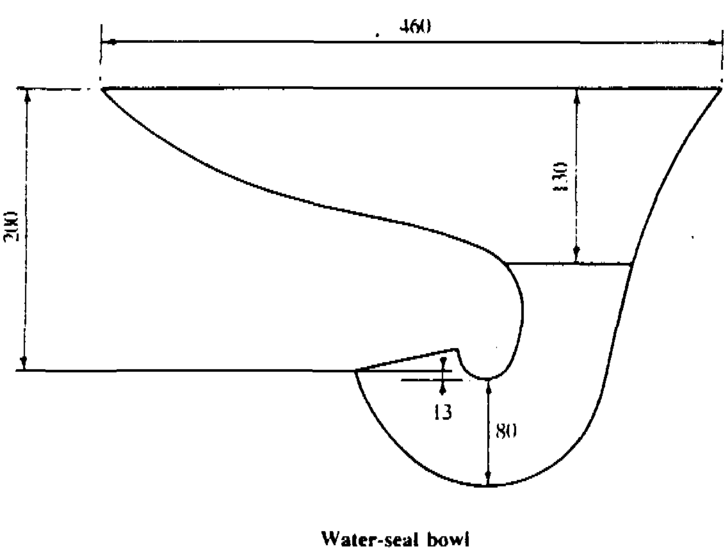


Fig. 7 Galvanized sheet-metal water-seal unit for PF toilets located immediately above the pit

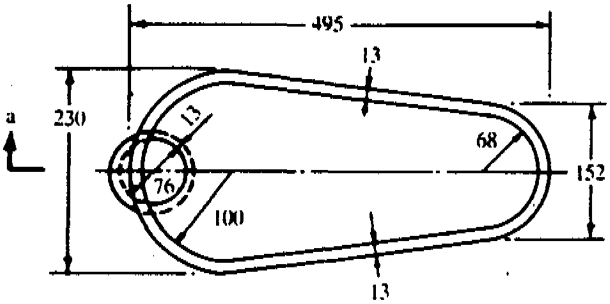




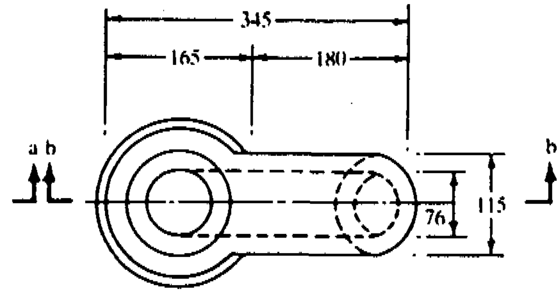
Source: Adapted from Wagner and Lanoix (1958).

Fig. 8 Plastic or fibreglass water-seal toilet

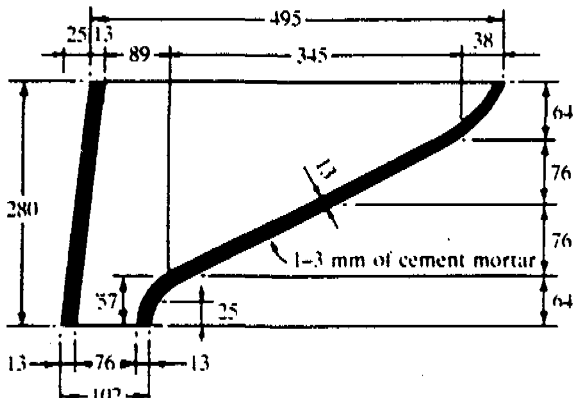
A. Cement mortar or ceramic pan



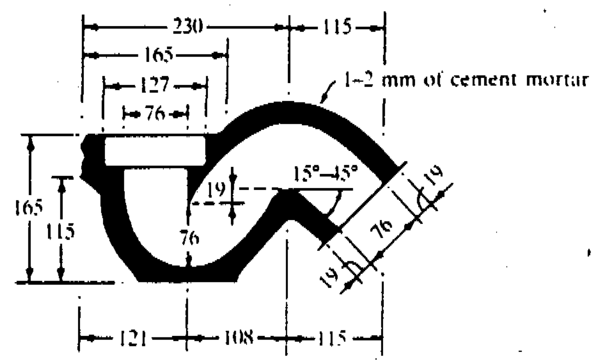
Plan of squatting plate (pan)



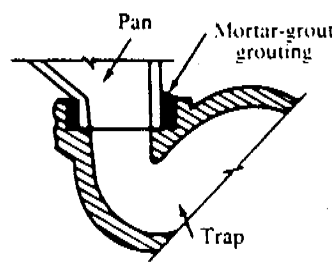
Plan of water-seal unit (trap)



Section a-a

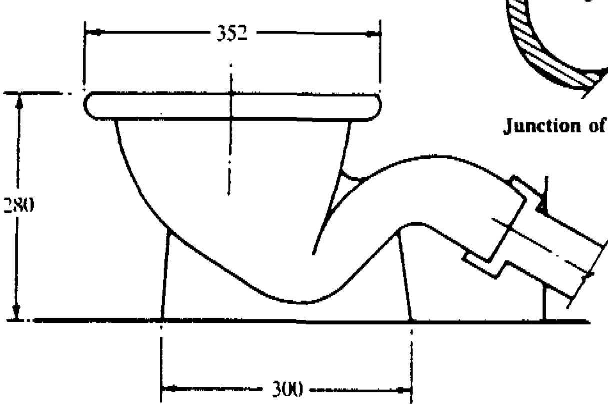


Section b-b

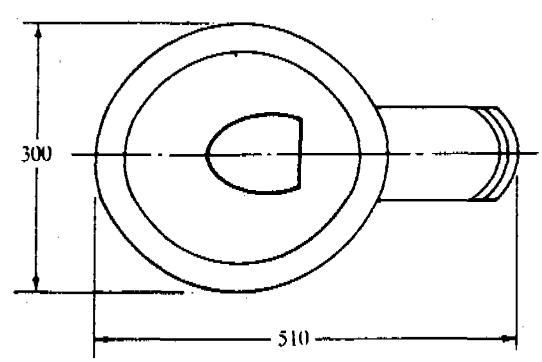


Junction of pan trap

B. Ceramic pedestal



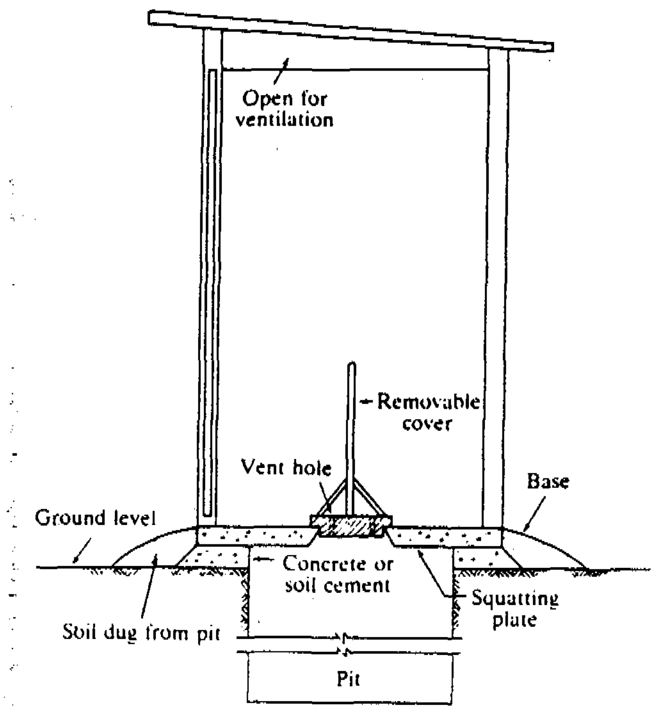
Side view



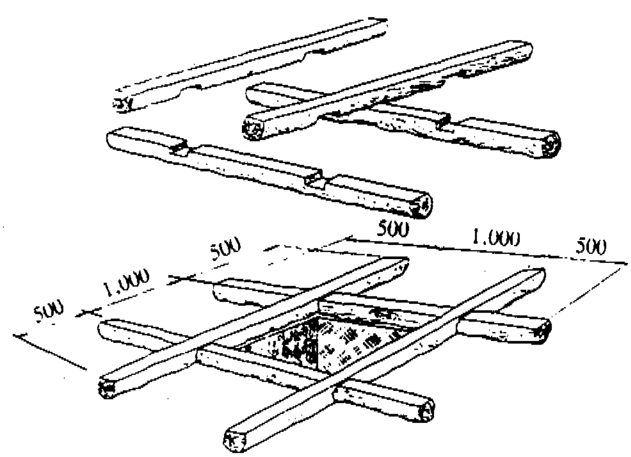
Top view

Sources: A adapted from Wagner and Lanoix (1958); B adapted from CIMDER (Center for Multidisciplinary Investigation's in Rural Development), Colombia.

Fig. 9 Pour-flush (PF) units for displaced pits



Side view

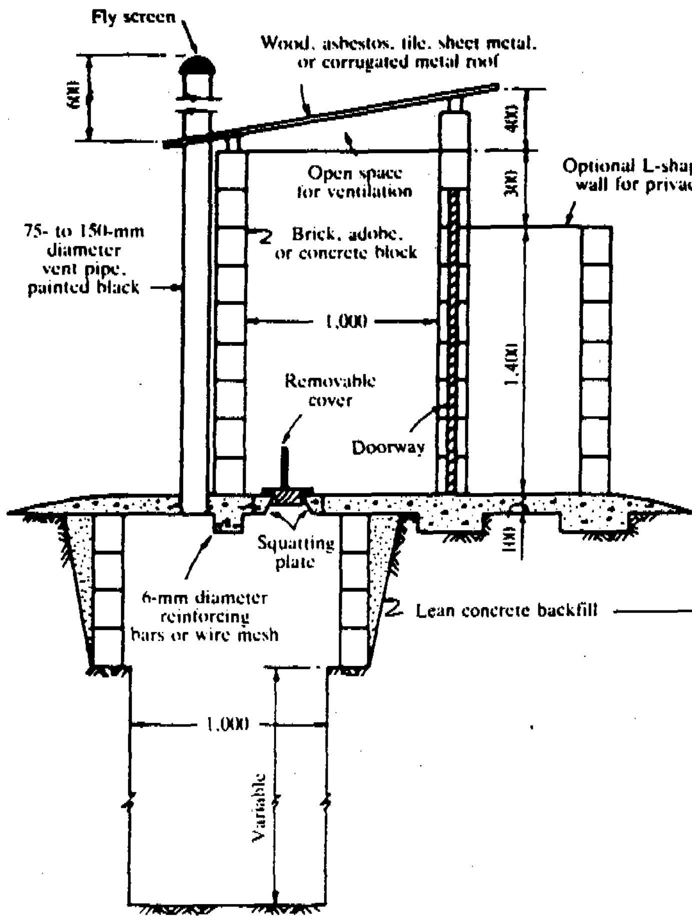


Alternative base using hewn logs

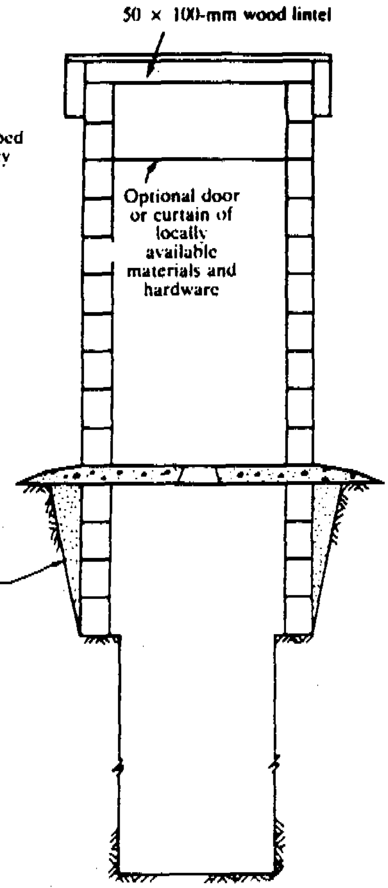
Note: In termite-infested areas, use treated wood or termite barrier.

Source: Adapted from Wagner and Lanoix (1958).

Fig. 10 Conventional unimproved pit latrine

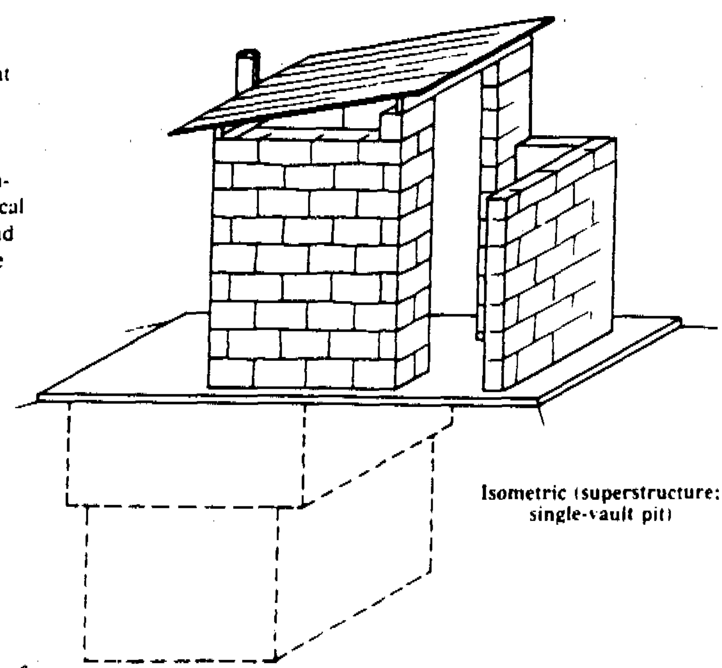


Side view (section)



Front view (superstructure: L-shaped wall and vent not shown)

Note: In the side view, a pedestal seat or bench may be substituted for the squatting plate. An opening for desludging may be provided next to the vent. Dimensions of the bricks or concrete blocks may vary according to local practice. Wooden beams, flooring, and siding may be substituted for concrete block walls and substructure.



Isometric (superstructure: single-vault pit)

Fig. 11 Ventilated improved pit (VIP) latrine

An alternative design for a VIP latrine is the Reed Odourless Earth Closet (ROEC) latrine shown in Figure 13. In this latrine, the pit is completely offset, and excreta is introduced into the pit via a chute.

Advantages of ROEC over VIP latrines are: (i) pit is larger and thus has a longer life than other shallow pits (ii) users (especially children) have no fear of falling into it (iii) excreta cannot be seen in the pit and the pit can be easily emptied, so that the superstructure can be a permanent facility. The disadvantage of this latrine is that it is easily fouled with excreta and thus may provide a site for flies breeding. Figure 14 provides different pit designs used for conventional pit latrines. These latrines are designed for use without water, i.e., there is no need to flush excreta into the pit.

2.3. Composting toilets: Household systems for composting night soil and other organic materials are used under a variety of conditions and are successful in both developing and industrial countries. Composting toilets for this purpose are of two kinds: (a) continuous (b) batch.

(a) Continuous composting toilets: These are onsite aerobic composting toilets often referred to as the "Multrum", which was invented by Lindstrom. These toilets have been in commercial production for more than 20 years. Figure 15 and 16 are such type of toilets. A Multrum consists of a water tight container with a sloping bottom. Human excreta is introduced at the upper part of the container with a sloping bottom. Human excreta is introduced at the upper part of the container, and mixed with organic kitchen and garden wastes (grass, straw, sawdust etc.), introduced lower down, to increase the carbon- nitrogen ratio.

Biopit toilet (Figure 17) which is the modification of Multrum toilet incorporates a gravel soakage pit to treat and dispose of the the liquid waste present in excreta.

(b) Batch composting toilet: These are onsite anaerobic composting toilets. Simplest kinds of batch composting toilets are pit latrines. The excreta deposited into the pit is decomposed anaerobically. When the pit is about 2/3rd full, it is filled up with dirt & left there for approximately 2 to 3 years so that excreta will be stabilized and pathogens will be inactivated, rendering it satisfactory for use as a soil conditioner. Some of the toilets in use are shown in Figures 18, 19, 20. The VIP latrine (Figure 21) is also in major use and is more favourable from the sanitation point of view. Vietnamese toilet as shown in Figure 22 is also claimed to be the key component of a rural sanitation program for disease prevention and fertilizer.

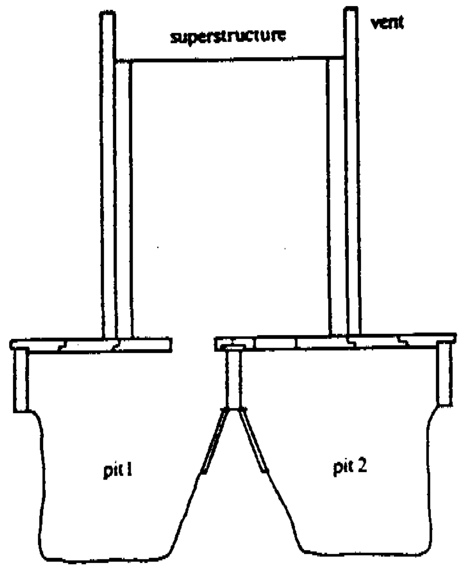


Fig. 12 Ventilated Improved Double Pit (VIDP) Latrine

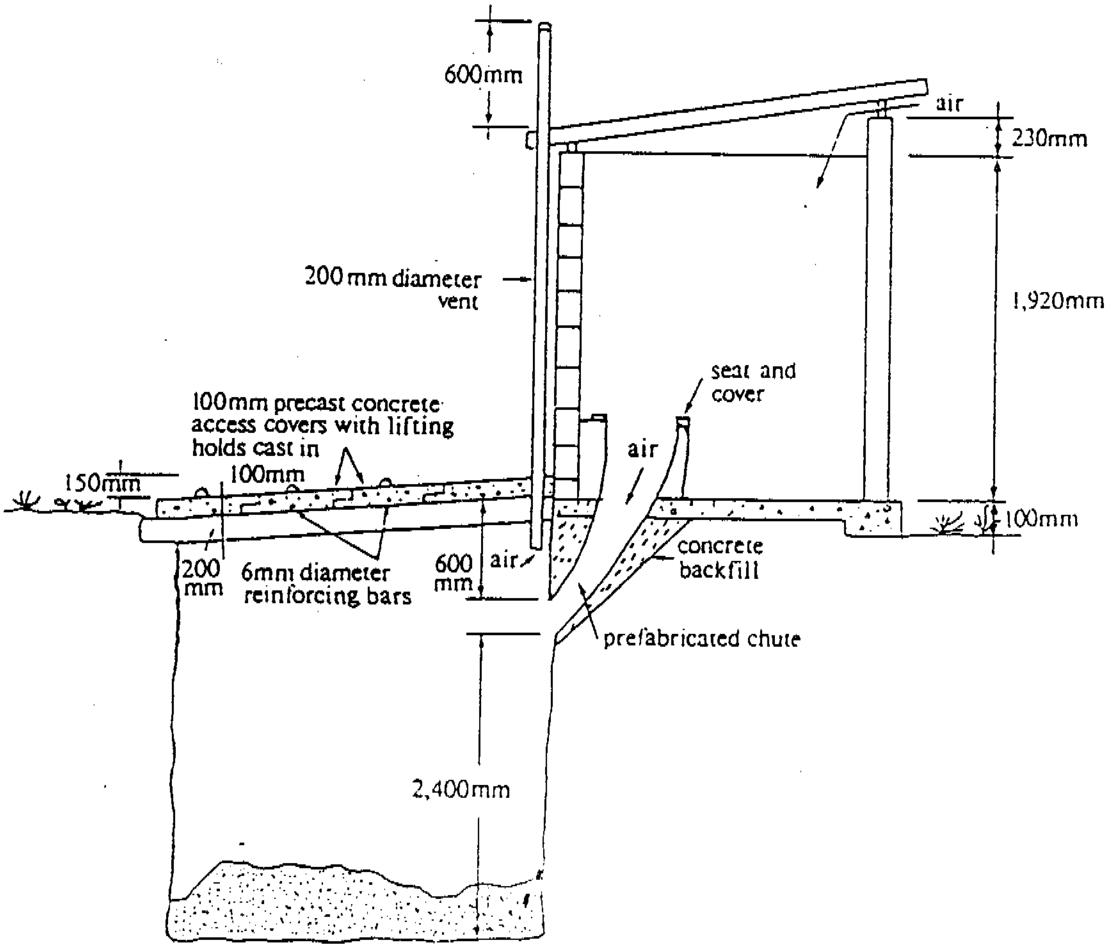
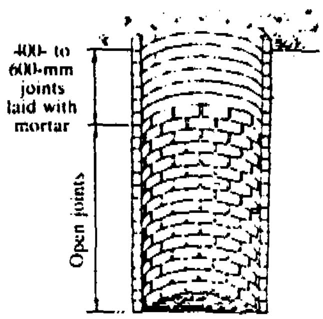
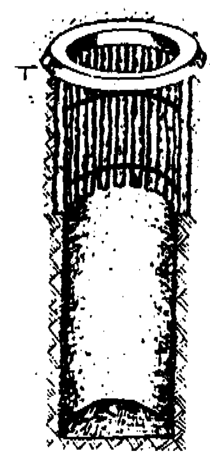


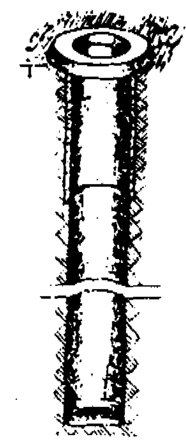
Fig. 13 The reed odourless earth closet (ROEC)



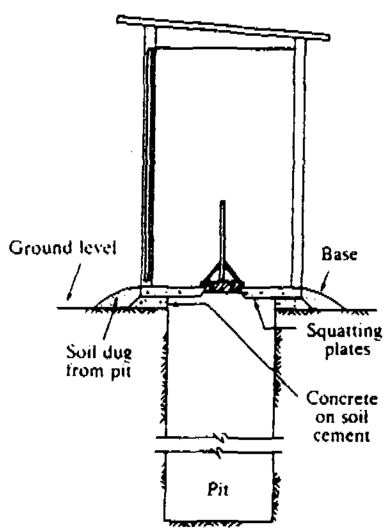
Circular pit with brick lining



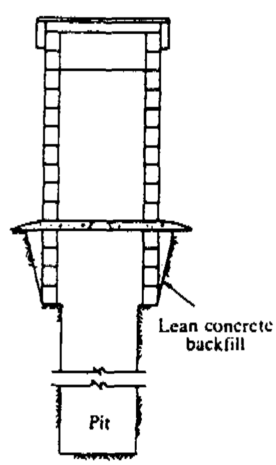
Round pit with partial lining of tree limbs



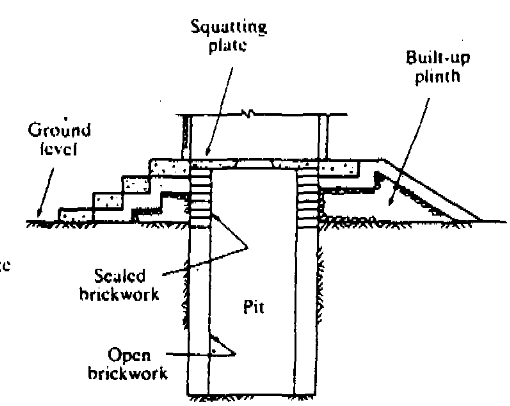
Bored pit with concrete lining



***Unlined* pit**



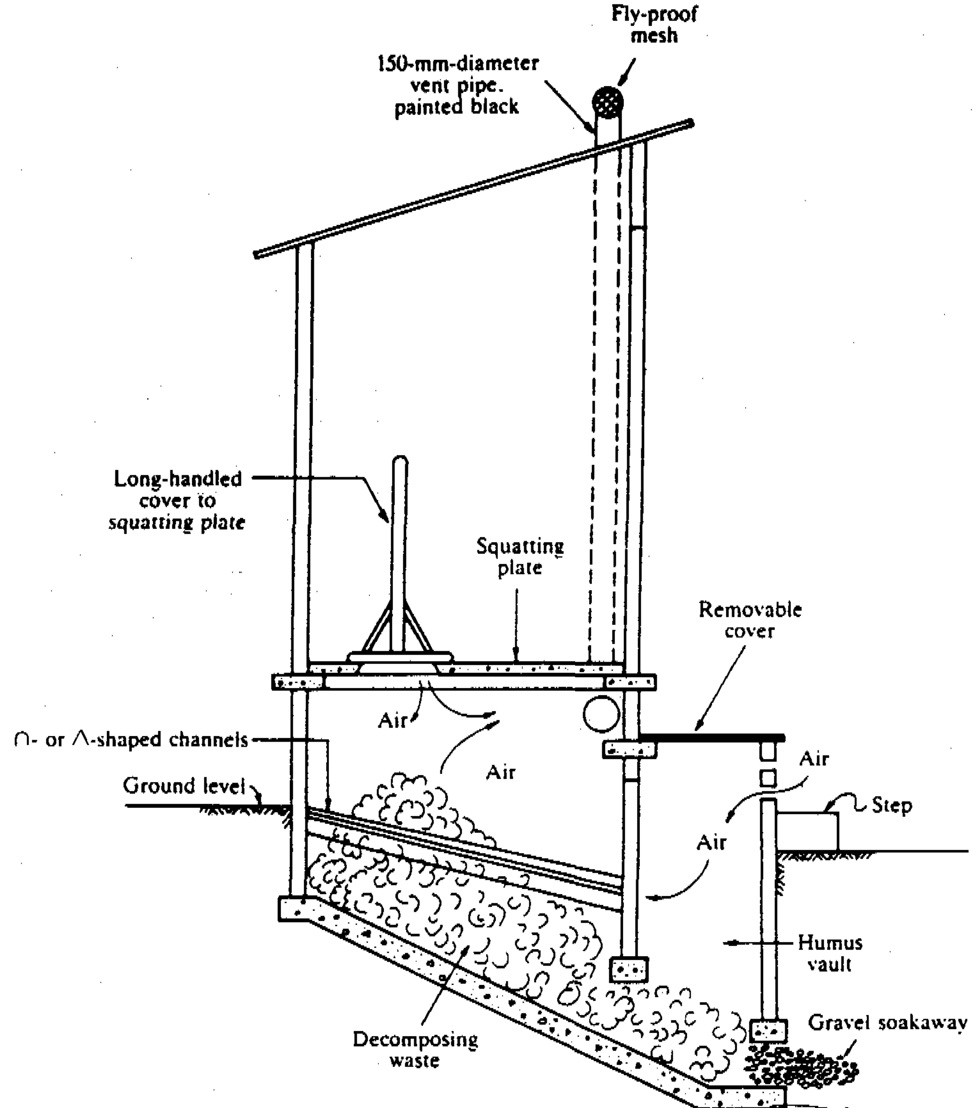
Square pit with partial concrete-block lining



Raised pit latrine for use in areas of high groundwater table

Sources: Top row, adapted from Wagner and Lanoix (1958); bottom row, World Bank.

Fig. 14 Alternatives pit designs



Source: Adapted from a drawing by U. Winblad.

Fig. 15 "Multrum" continuous-composting toilet

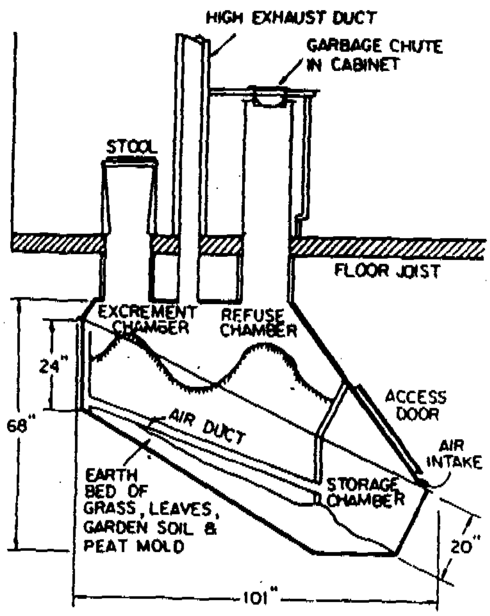


Fig. 16 The Clivus Multrum toilet (Rybczynski et al.,1978)

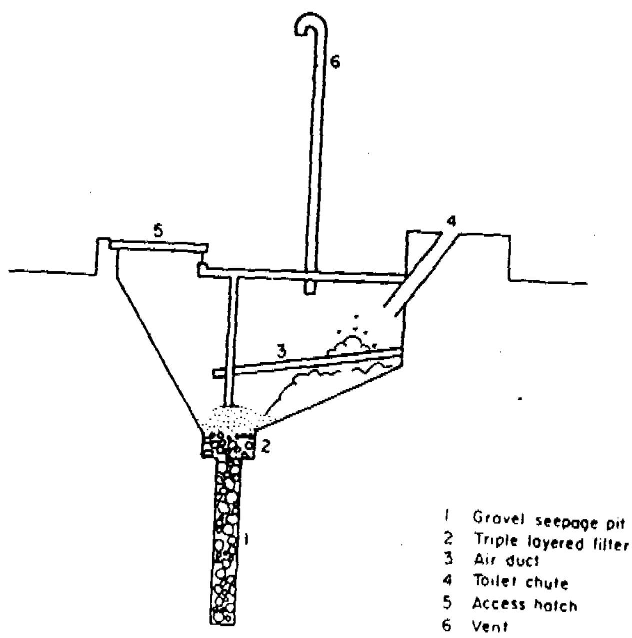


Fig. 17 The biopit composting toilet (Rybczynski et al.,1978)

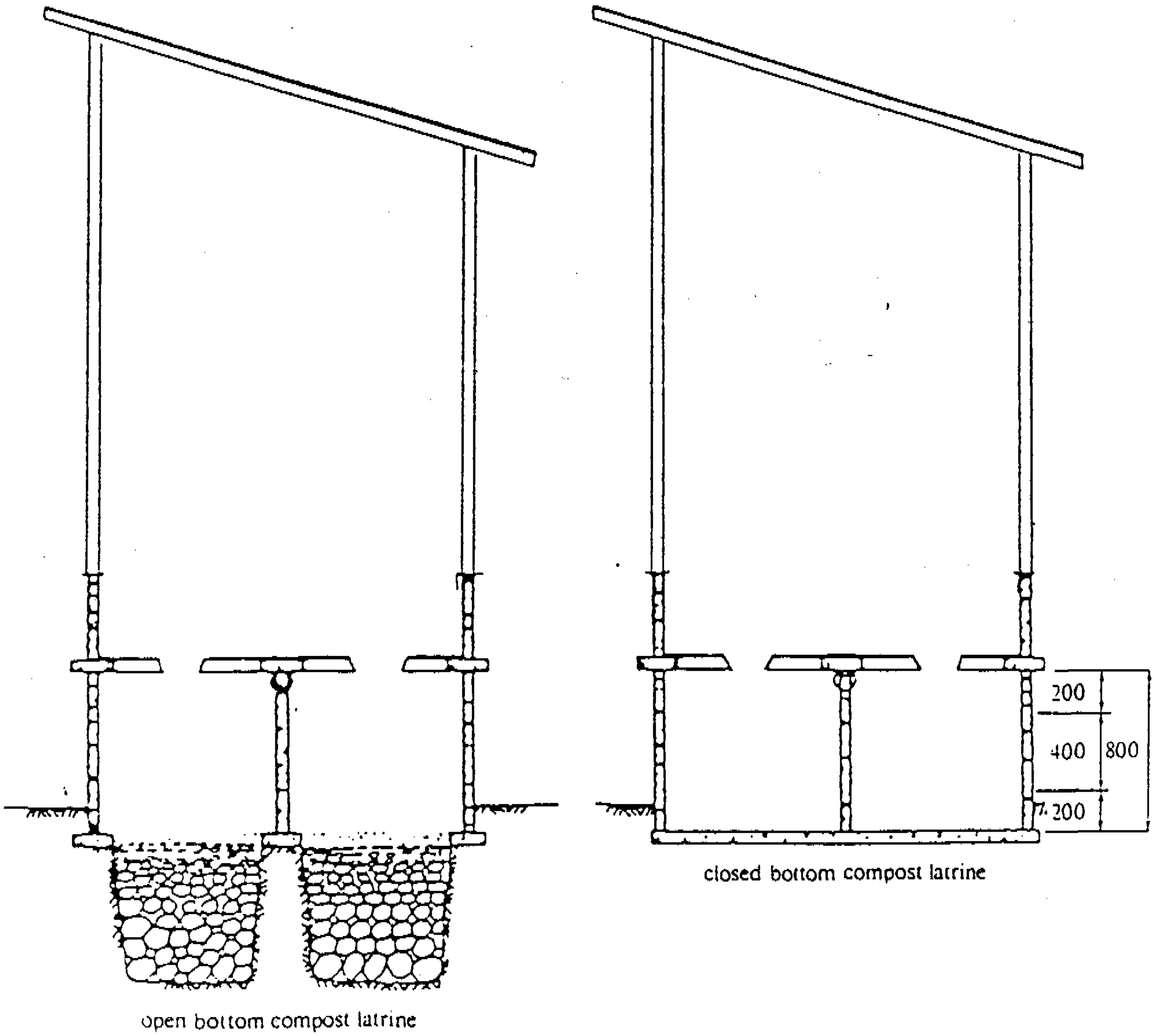


Fig. 18 The African batch compost toilet

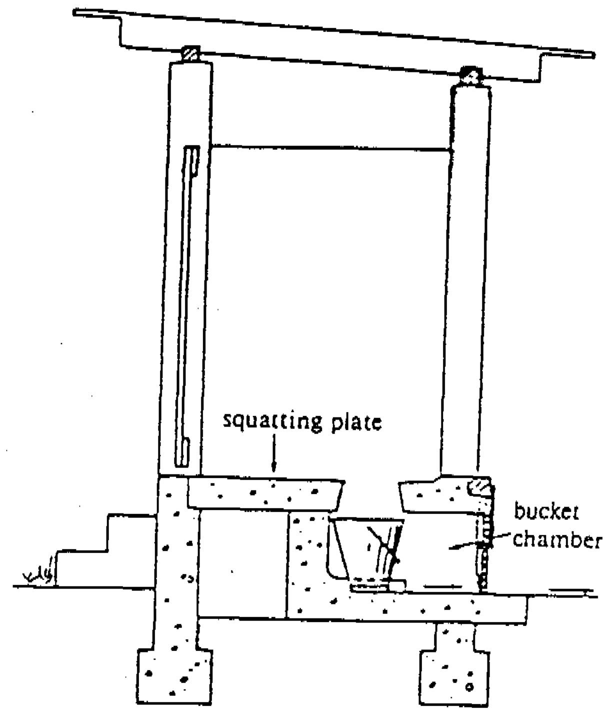


Fig. 19 A bucket latrine with squatting plate

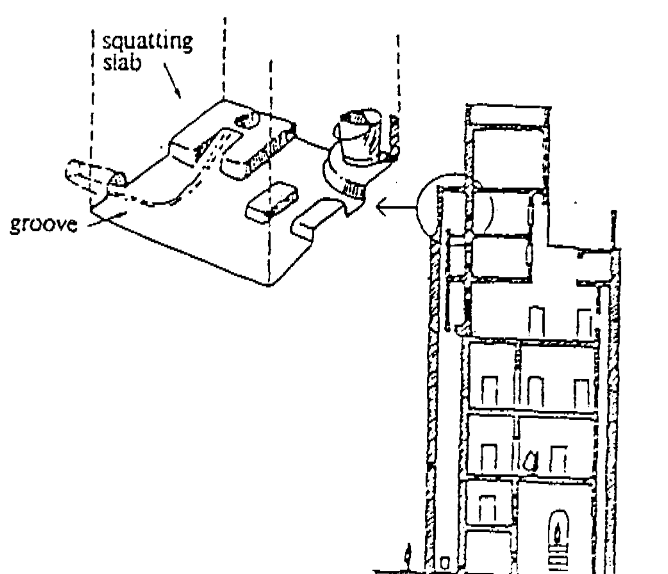


Fig. 20 The Yemen long drop latrine

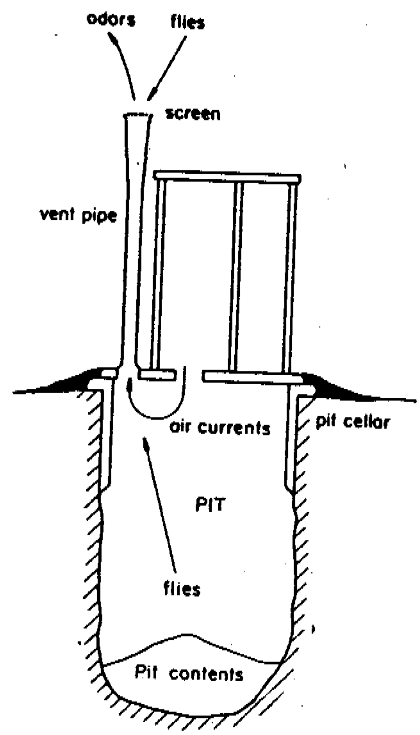


Fig. 21 The schematic diagram of ventilated improved pit latrine (Morgan and Mara,1982)

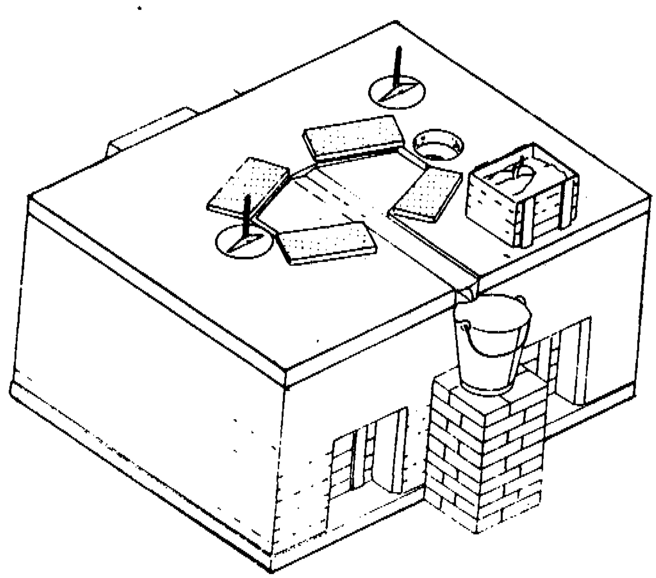


Fig. 22 The Vietnamese composting toilet

2.4.(a) Pour-flush (PF) toilets: A further improvement to the pit latrine can be obtained with a water seal, which is a U-pipe filled with water, below the seat or squatting pan and which completely prevents the passage of flies and odours. This type of toilet has three major advantages: low water requirements; complete odour and fly elimination by the shallow water seal; and they can be located, if desired, inside the house, and not necessarily only on the ground floor. Figure 23 represents the pour-flush toilet connected with septic tank systems (soakaway, drainfield and sewer).

2.4.(b) Aquaprivies: The aquaprivy is a watertight settling tank to which wastes are carried by water flushing down a short sewer and which is located directly underneath a squatting plate. It has a 100 to 150 mm diameter vertical drop pipe extending 100 mm below the liquid level in the tank. Two different aquaprivy systems are presented in Figures 24 and 25.

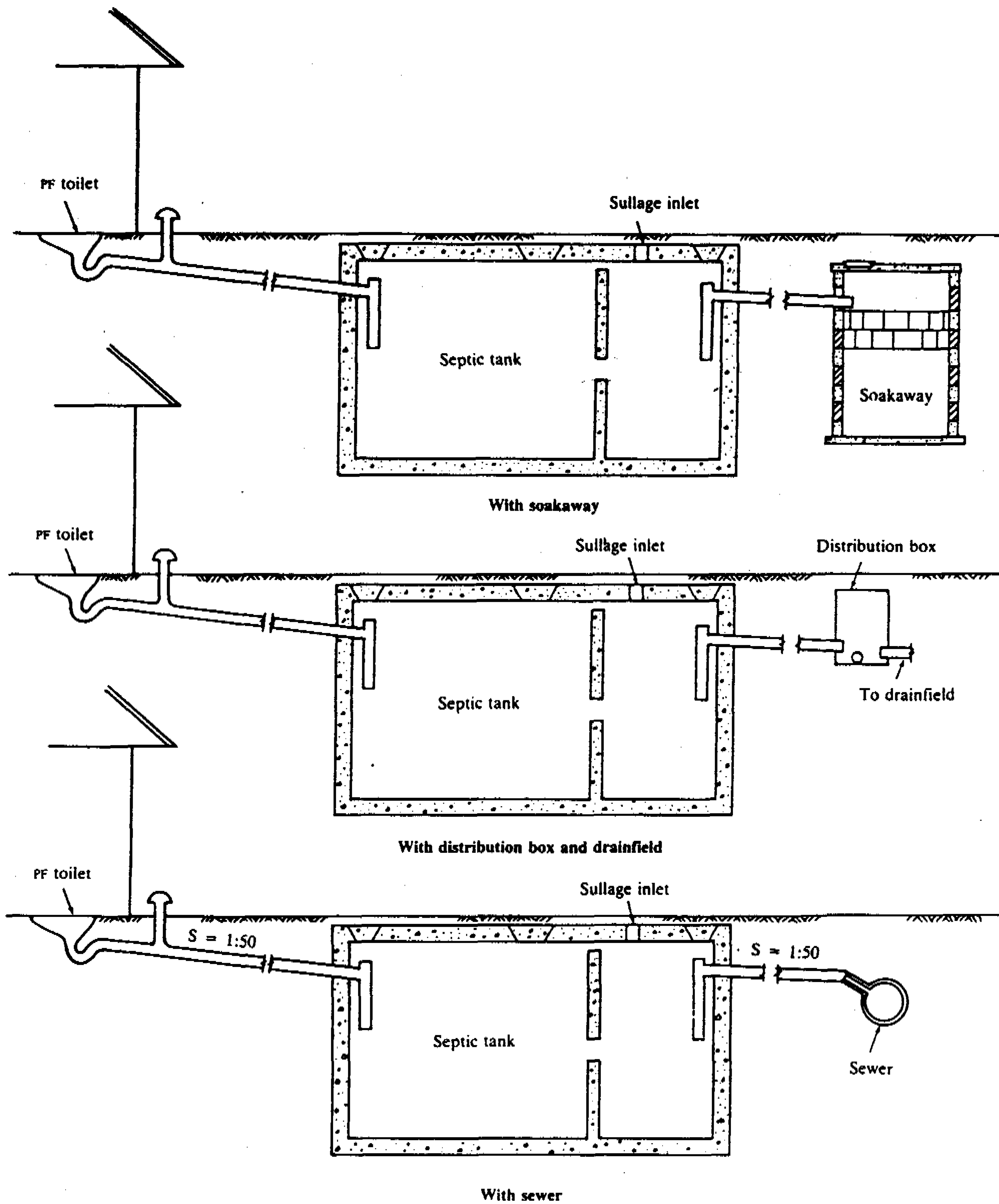
Figure 26 is the improved type of the aquaprivy with sullage disposal. This type of aquaprivy is more useful where the common anal cleansing materials would clog the water seals of PF toilets.

2.4.(c) Septic tanks, soakaways and drainfields: Septic tanks are rectangular chambers which are, usually, below ground level, that receive both excreta and freshwater from flush toilets and other household wastewater. The mean hydraulic retention time in the tank is usually one to three days. At this period, the solid portion settles down to the bottom where it can be digested anaerobically and a thick layer of scum is formed at the surface. A schematic diagram of the conventional septic tank is shown Figure 27. This is a two compartment septic tank which is generally preferred to the one with only a single compartment because the concentration of suspended solids in its effluent is considerably lower. The first compartment is almost double the size of the second.

Figure 28 shows a variety of alternate septic tank designs, including an experimental septic tank in which an anaerobic upflow filter is substituted for subsurface system for effluent disposal.

Figure 29 is an example of a soakaway in which the septic tank effluent is discharged directly. Similarly, Figure 30 shows a number of drainage trenches connected in series where the effluent is discharged. Each trench consists of open-jointed drainage tiles of 100 mm diameter laid on a one meter depth of rockfill.

In those areas where the water table is near the surface or the soil percolation capacity is insufficient, an evaporation mound (Figure 31) may be substituted for a drainfield.



S Slope.

Fig. 23 Pour-flush toilet- septic-tank systems

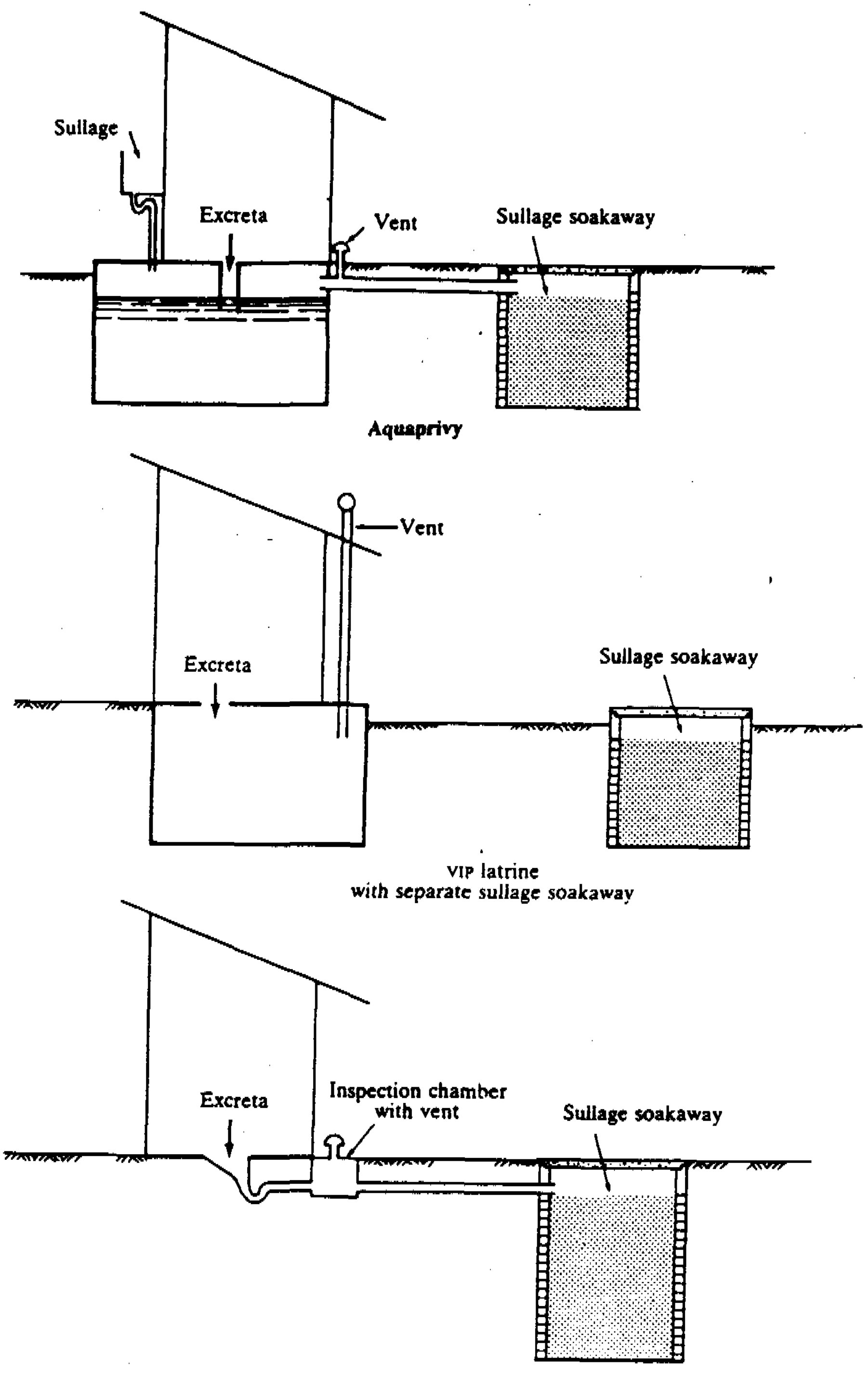
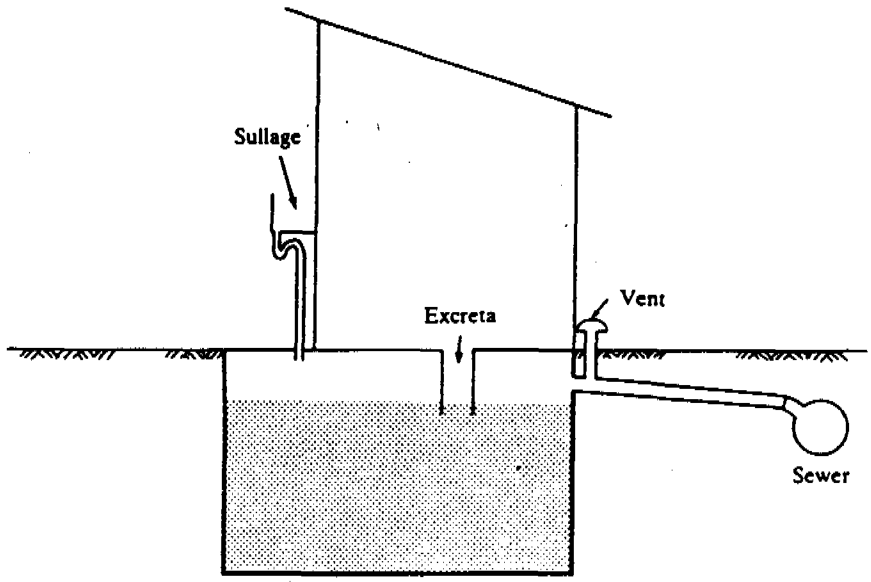
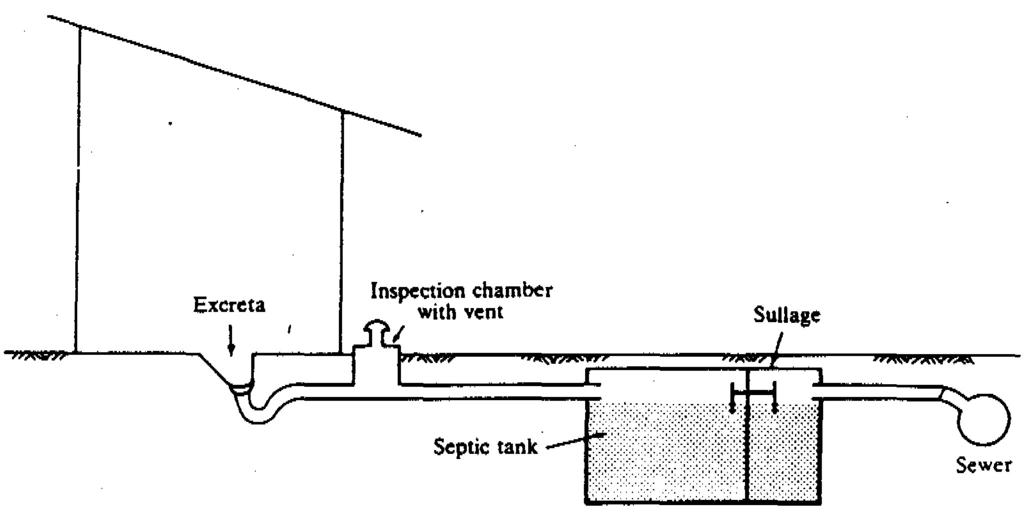


Fig. 24 Formal equivalence of sullage aquaprivy to VIP latrine with separate sullage soakaway to PF toilet

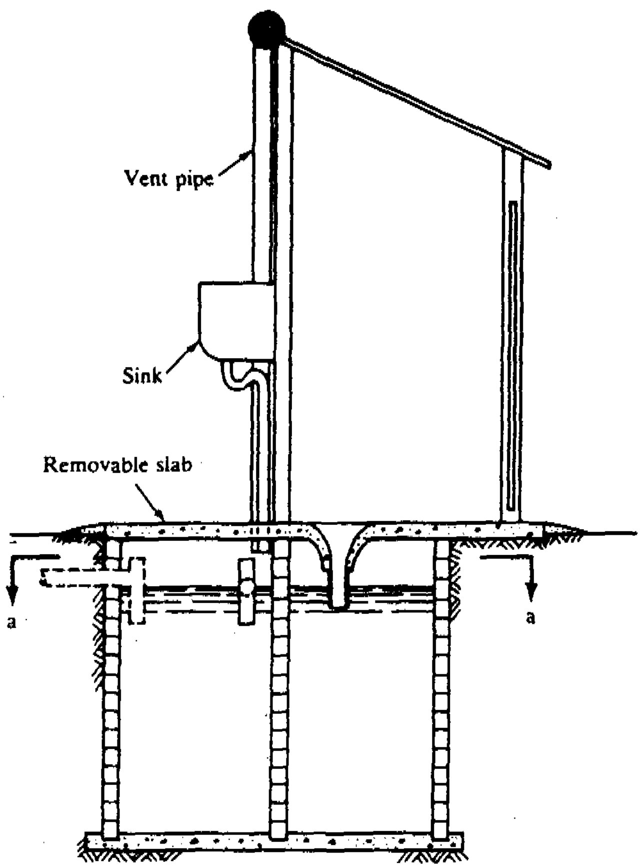


Sewered aquaprivy

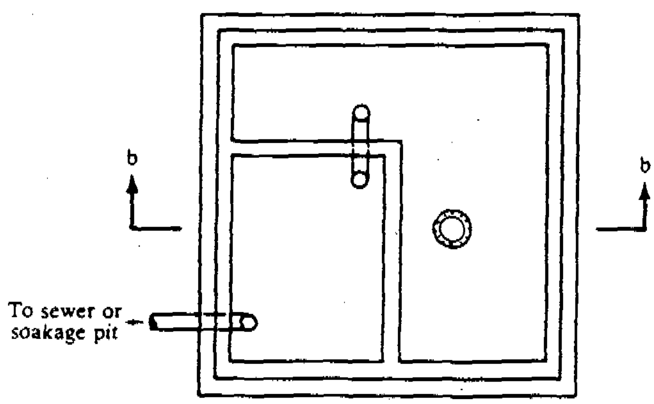


Sewered PF toilet

Fig. 25 Formal equivalence of sewered aquaprivy to sewered PF toilet



Section b-b



Plan/section a-a

Fig. 26 Improved sewered aquaprivy with sullage disposal

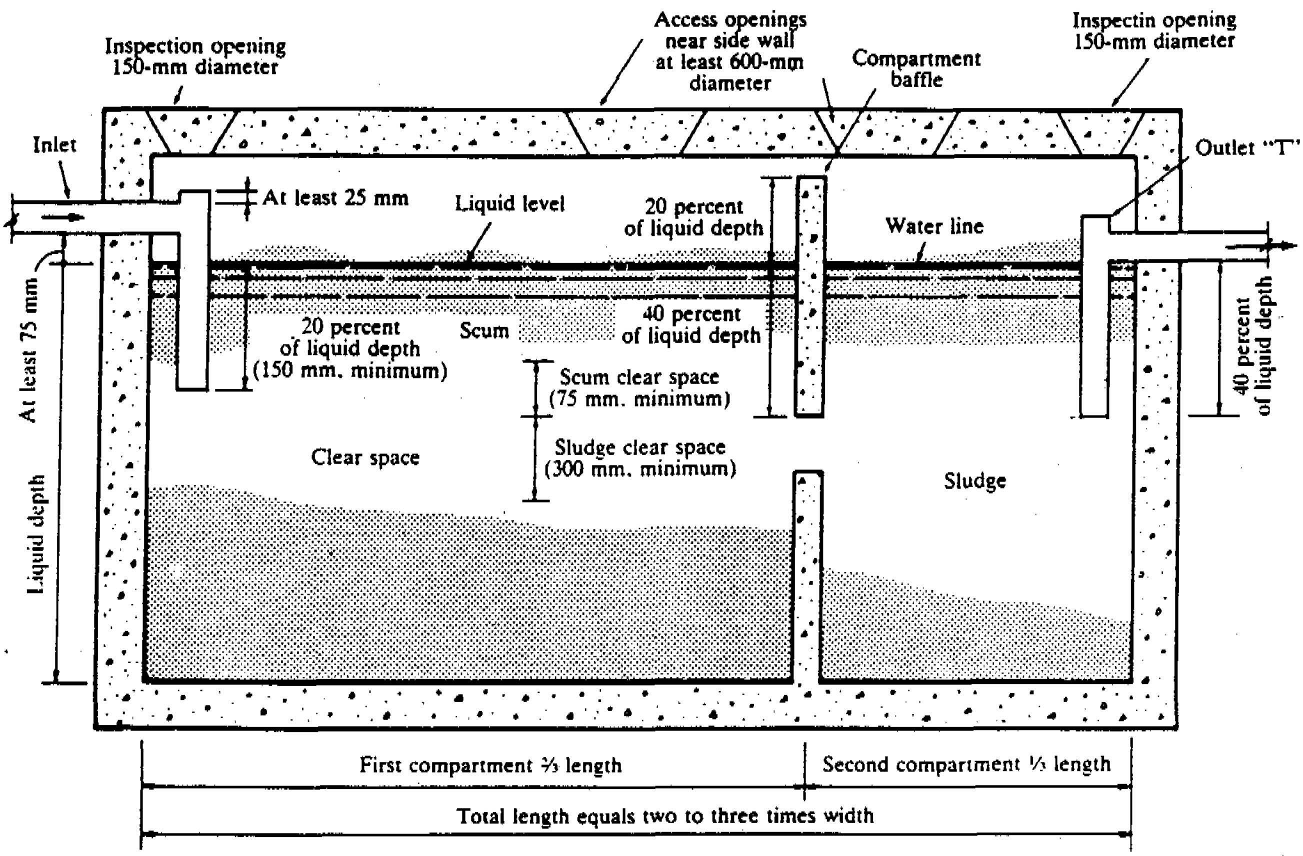
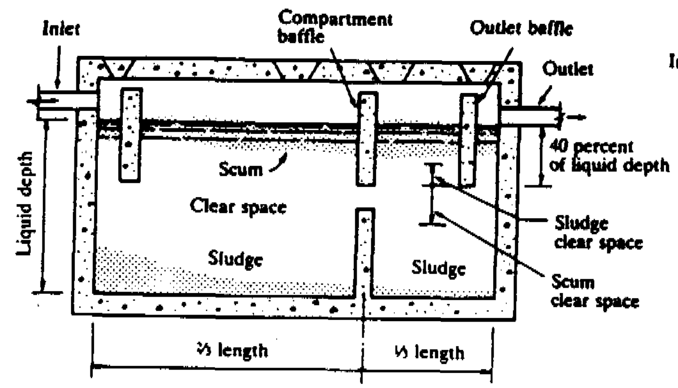
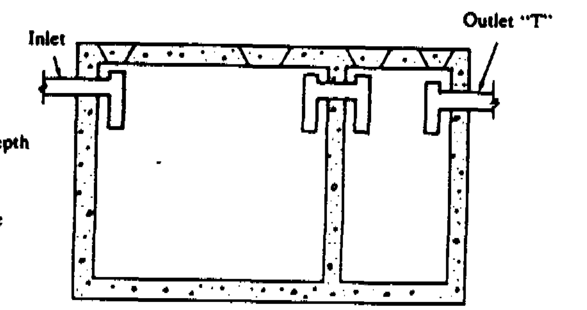


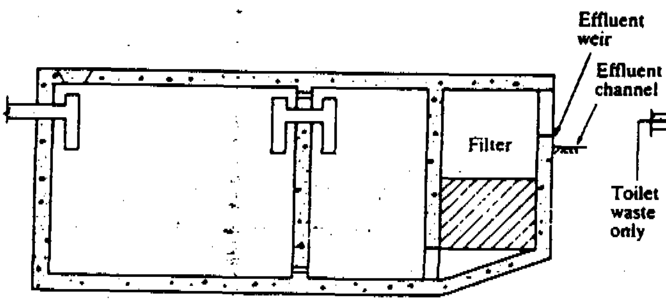
Fig. 27 Schematic of conventional septic tank



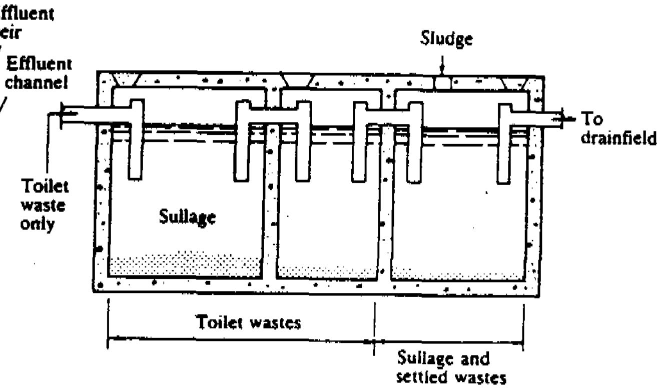
Conventional two-compartment septic tank with baffle walls



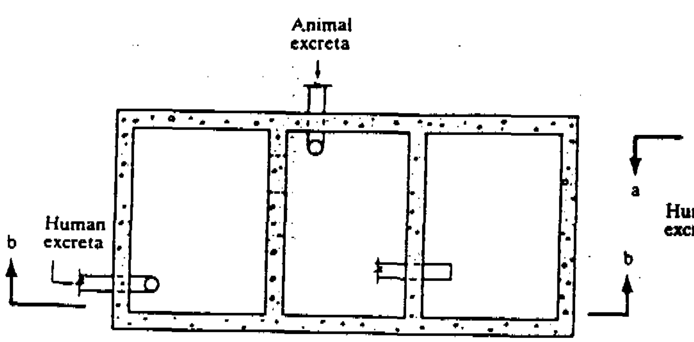
Conventional two-compartment septic tank with inlet connector and outlet "T"



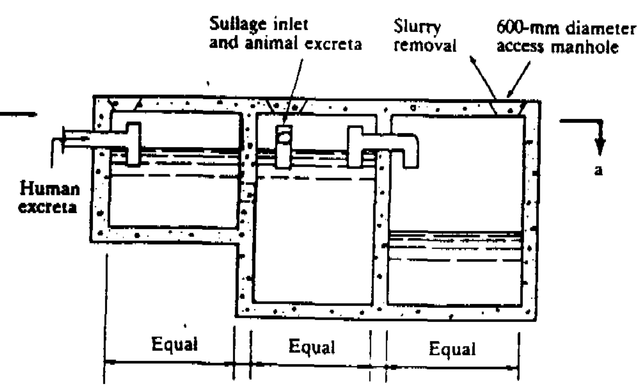
Two-compartment septic tank with upflow filter



Three-compartment septic tank



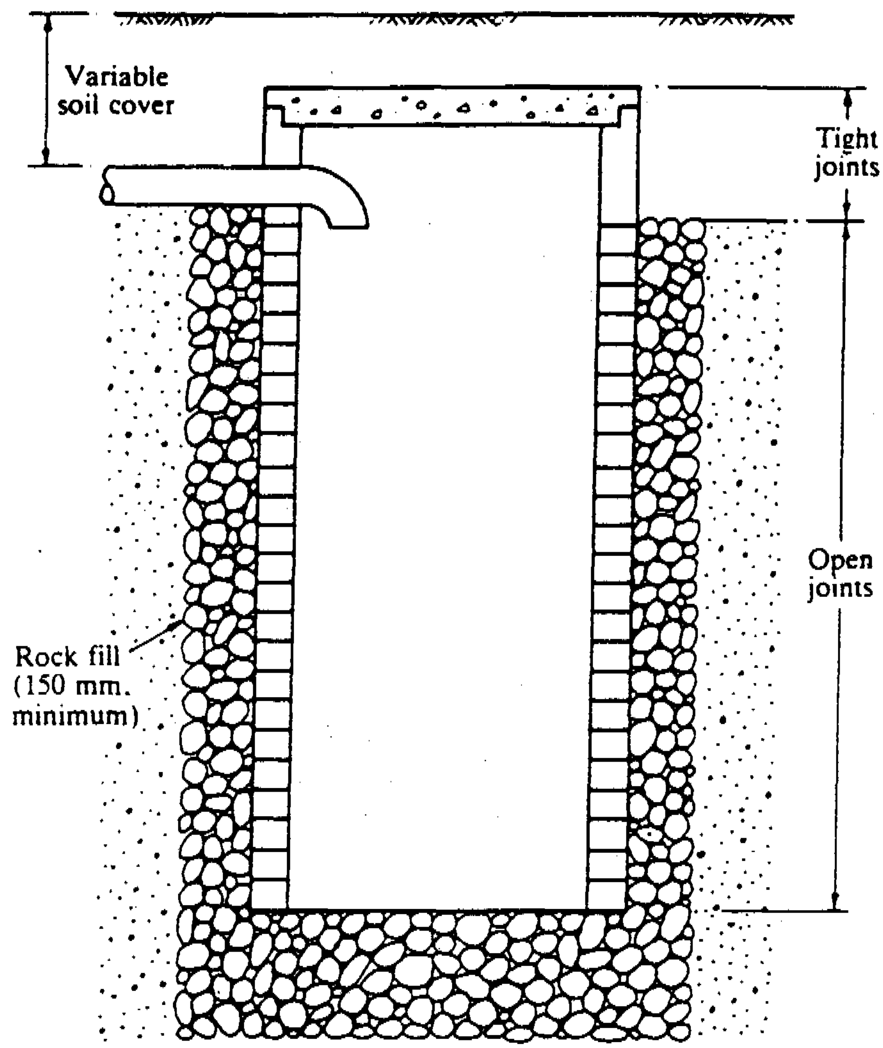
Section a-a



Section b-b

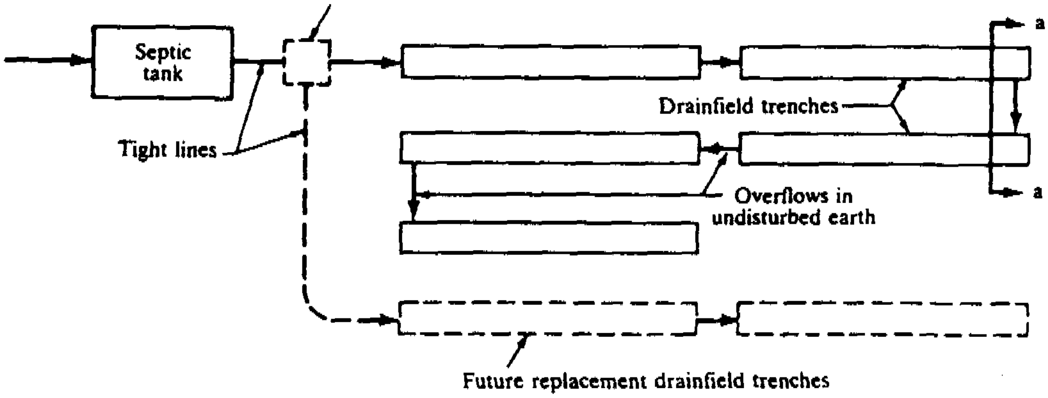
Three-compartment septic tank for resource recovery

Fig. 28 Different septic tank designs

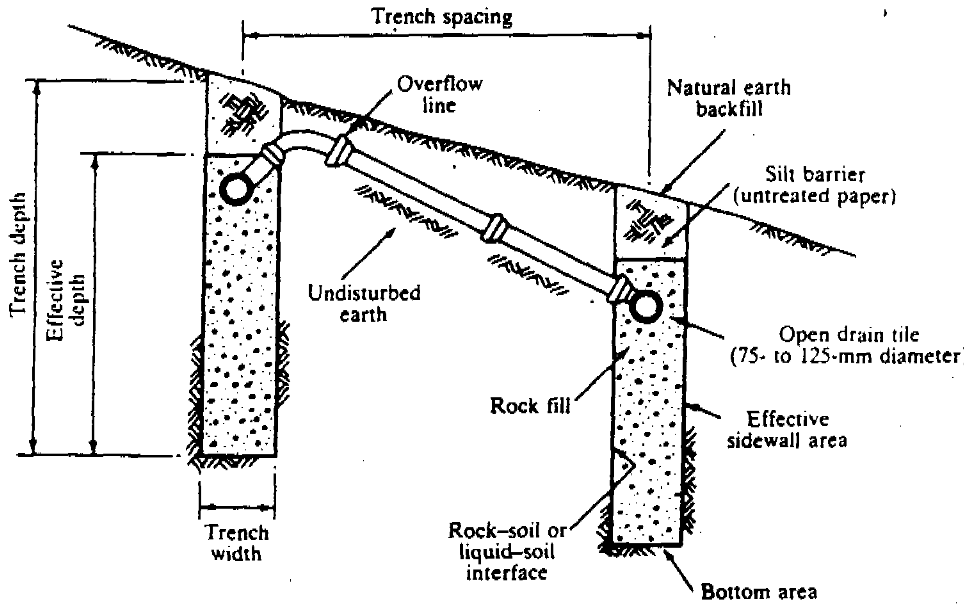


Source: Adapted after Wagner and Lanoix (1958).

Fig. 29 Schematic of a soakaway



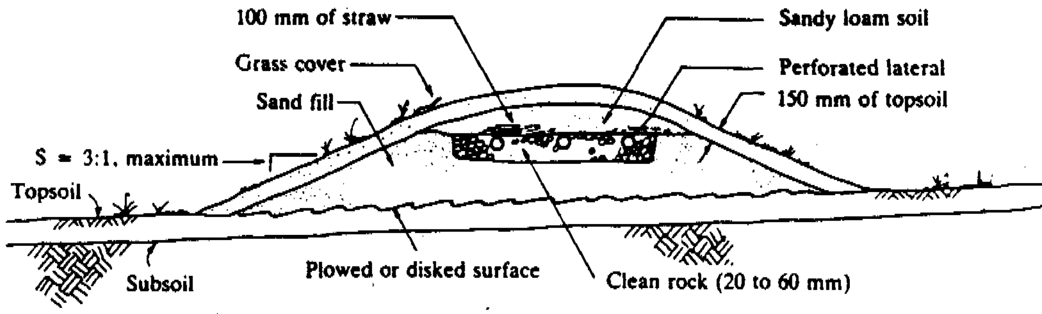
Plan



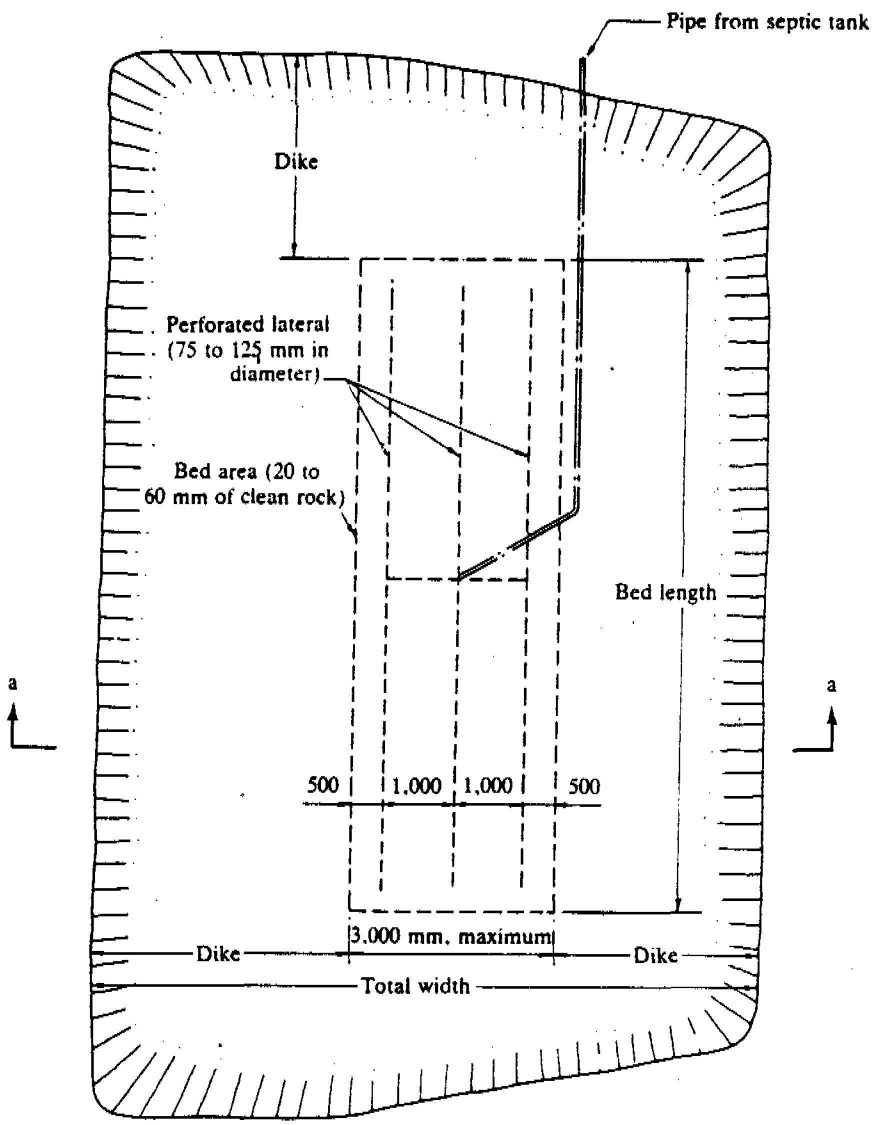
Section a-a

Source: Adapted from Cotteral and Norris (1969; © American Society of Civil Engineers; original used by permission).

Fig. 30 Drainfield for septic tank effluent



Cross section a-a



Plan/top view

S Slope.
Note: An acceptable alternative to a mound is an evapotranspiration bed, which has the same construction but is built in a natural or manmade depression not subject to flooding and has a more or less level surface.

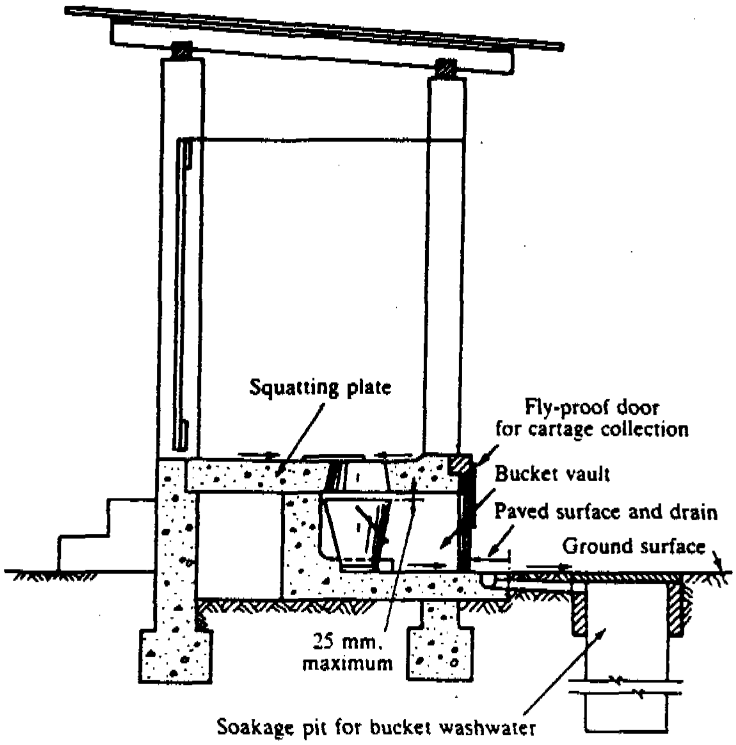
Fig. 31 Evapotranspiration Mound

2.5.(a) Bucket Latrine: It is a traditional type of latrine. This latrine consists of a squatting plate and a metal bucket located in a small compartment immediately below the squatting plate. Excreta is deposited into the bucket, which is periodically emptied by a night soil labourer into a large collection bucket. When it is full, it is carried into a night soil collection depot. Figure 32 is an example of a bucket latrine and cartage.

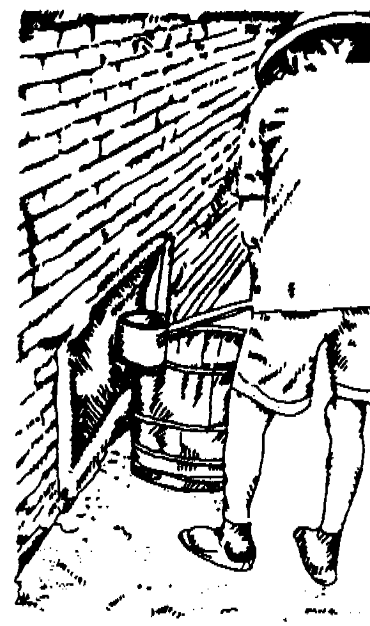
2.5.(b) Vault and cartage system: In this toilet (Figure 33), excreta is discharged into a sealed vault that is emptied at regular intervals. A vacuum tanker is preferred one to empty the vault.

This type of toilet can be installed as a PF toilet either *with the vault immediately below the squatting* plate or with a completely offset vault. In the later case, the vault may be shared by an adjacent house, with some savings in the construction cost.

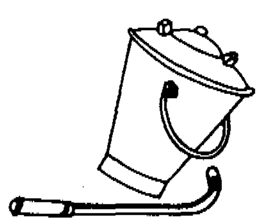
2.5.(c) Communal sanitation facility: It provides a minimum service level ranging from sanitation only to a combination of latrine, shower, and laundry units. Figure 34 is an example of the communal sanitation facility from which excreta as well as wastewater is discharged to the sewer.



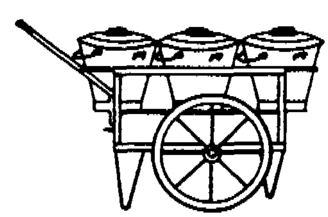
Bucket latrine



Night-soil collection by dipper and bucket
(here a vault rather than a bucket is located in house)



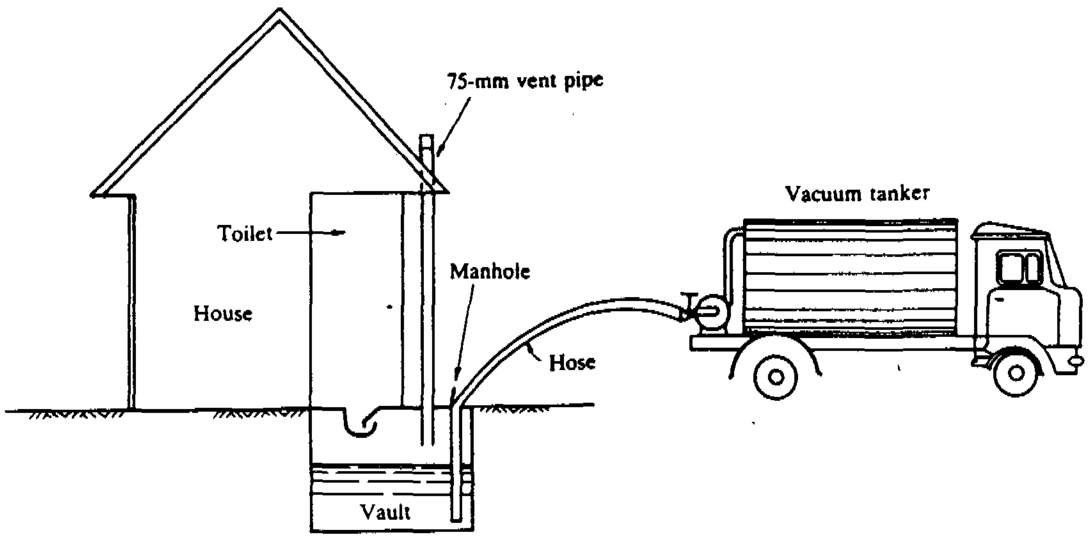
Night-soil bucket and scraper



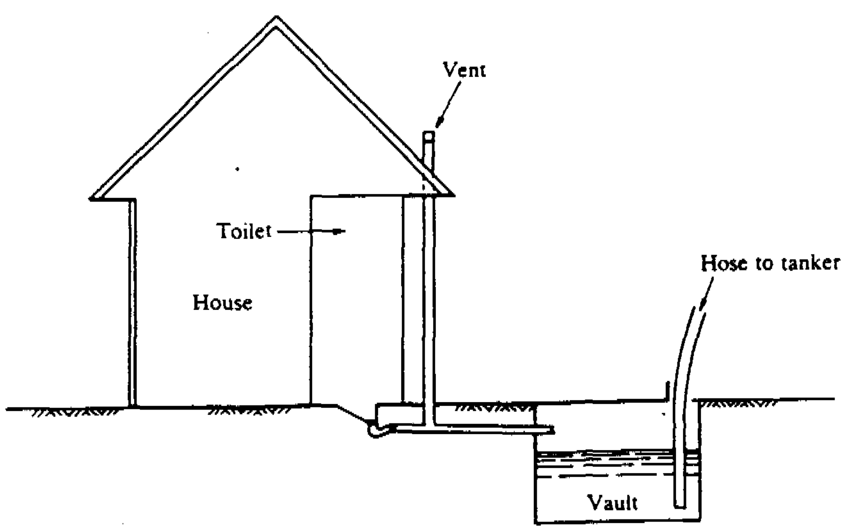
Cartage wheelbarrow for three or six buckets

Note: Fly-proof doors and paved surfaces and drains are commonly missing in most existing bucket latrines.
Sources: Top left, adapted from Wagner and Lanoix (1958); top right, from a photograph courtesy of Michael G. McGarry; bottom, Department of Social Welfare, Ahmadabad, India.

Fig. 32 Bucket latrines and cartage



Vault below squatting plate



Offset vault

Fig. 33 Alternative designs for vault toilets

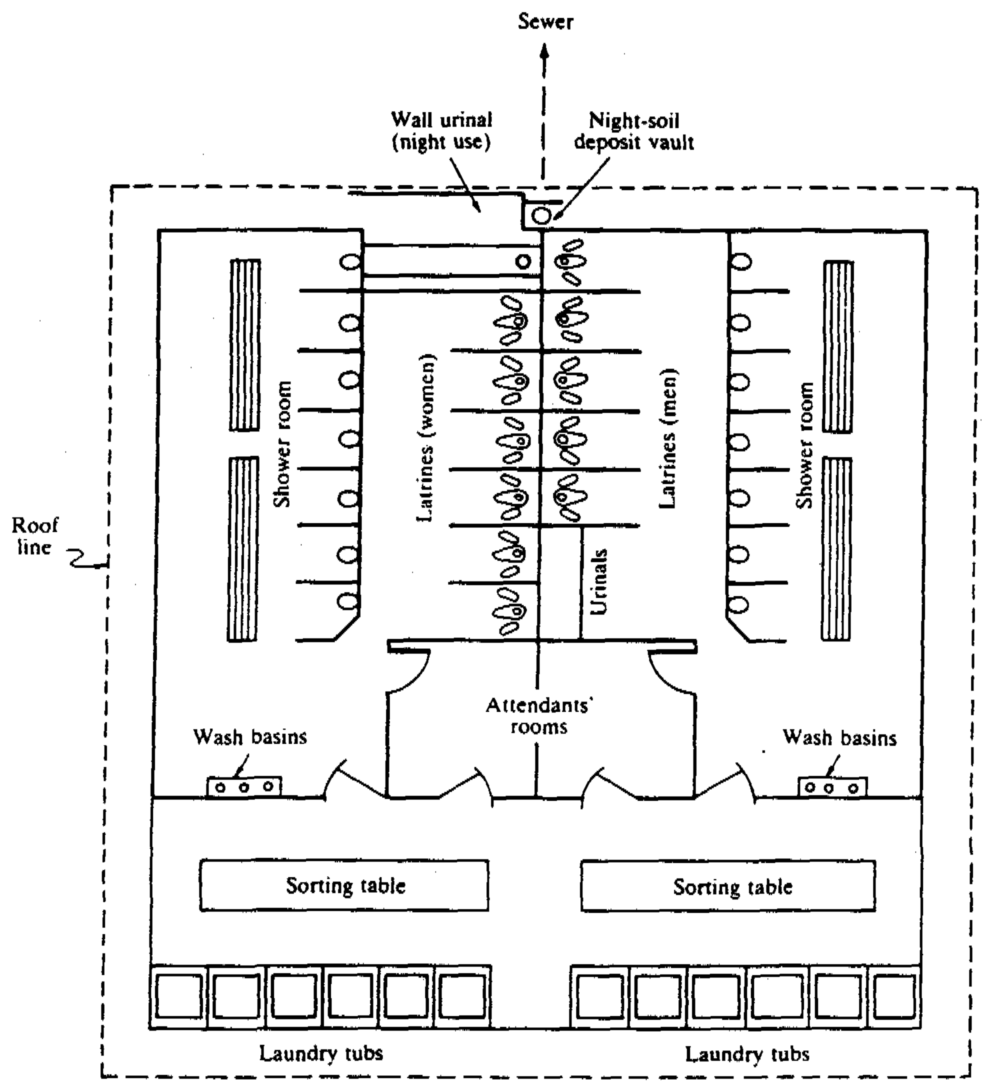


Fig. 34 Schematic of a communal sanitation facility

3. Offsite Treatment Technology:

The excreta and wastewater from the households are received to the sewer and collected in some central location for treatment. In some areas where there is no sewer facility, they may be collected by collection trucks to the central treatment plant. This type of treatment can be defined as offsite treatment.

The degree to which excreta and sewage are treated is largely influenced by what is to be done with the final solid and liquid products. For example for small flow discharge to the sea, a minimum treatment is sufficient. If the effluent has to be used for irrigation of food crops, a higher degree of treatment is needed.

Treatment of human wastes in developing countries has two principal objectives: the removal and destruction of excreted pathogens and the oxidation of the organic matter. The first objective is required to protect public health and the second to prevent pollution in the watercourse receiving the effluent.

Among many types of treatment systems, the most economic, easy and widely accepted as well as suitable in developing countries are presented below:

3.1. Waste Stabilization ponds: These are large shallow ponds in which organic wastes are decomposed by microorganisms in a combination of natural processes involving both bacteria and algae. Waste stabilization ponds can treat raw sewage, the effluent from sewered PF toilets, diluted night soil, or sullage. This is the most economical method of sewage treatment wherever land is available at relatively low cost. Three types of ponds are in common use:

- Anaerobic pond which functions as an open septic tanks & have retention time of 1 to 5 days & depths of 2 to 4 m.

- Facultative pond in which oxygen is necessary for biooxidation of the organic material. The oxygen is supplied principally by photosynthetic algae which grow in them naturally and with great profusion. They have retention times of 1 to 5 days.

- Aerobic maturation pond receive facultative pond effluent and is responsible for the quality of the final effluent. It has a retention time of 5 to 10 days and depths of about 1 to 1.5 meters.

Anaerobic and facultative ponds are designed for BOD removal, whereas, the function of the maturation pond is the destruction or the removal of excreted pathogens. Normally these three types of ponds should be used in conjunction to form a series of ponds. Figure 35 through 38 present some layouts and design details of waste stabilization ponds.

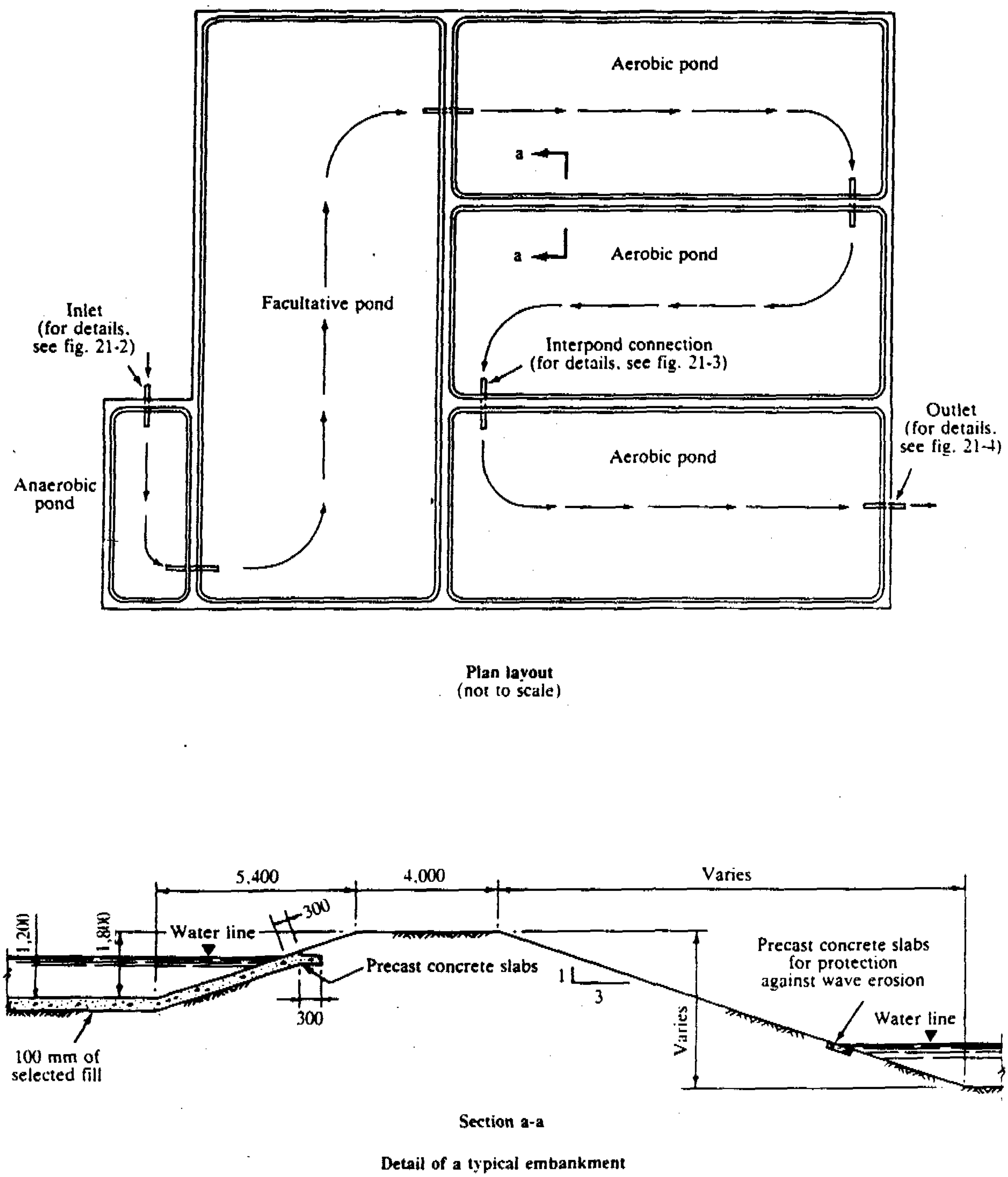
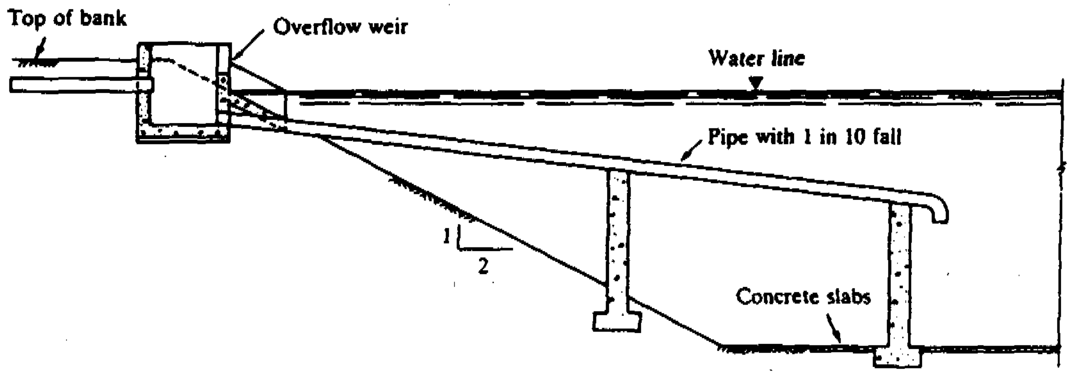
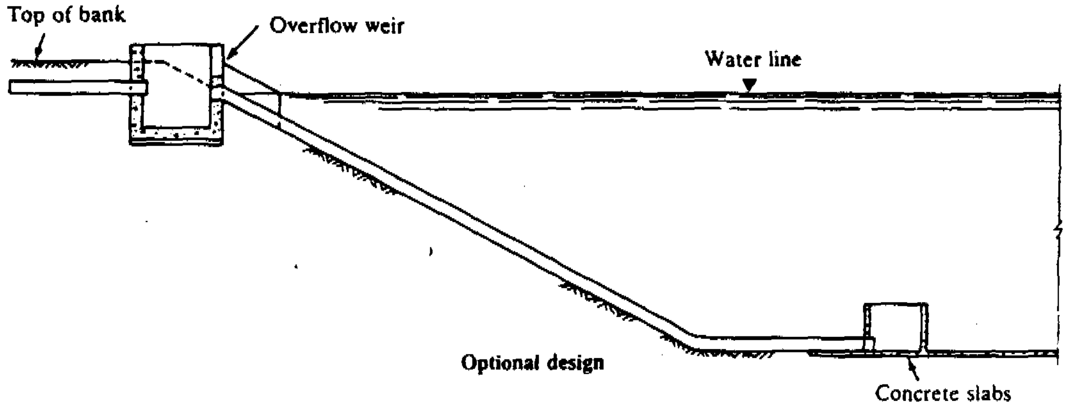


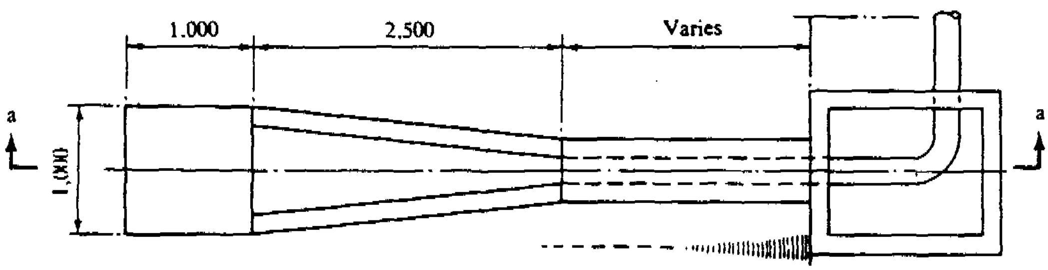
Fig. 35 Stabilization pond layout details



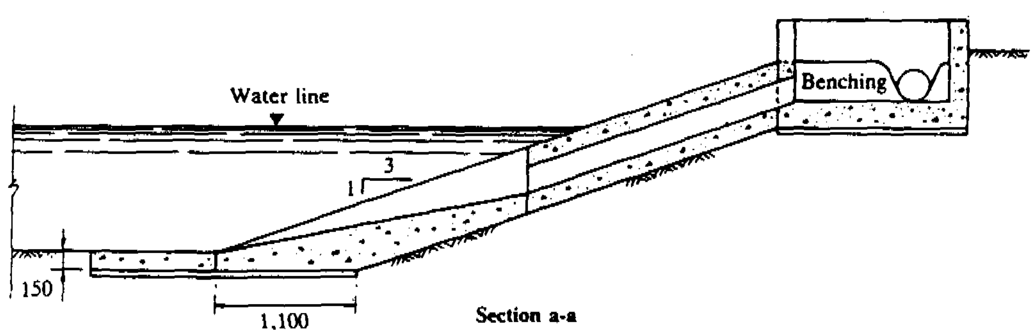
Inlet arrangement for a deep anaerobic lagoon
(the pipe should discharge well away
from the embankment to avoid
the development of sludge banks)



Optional design



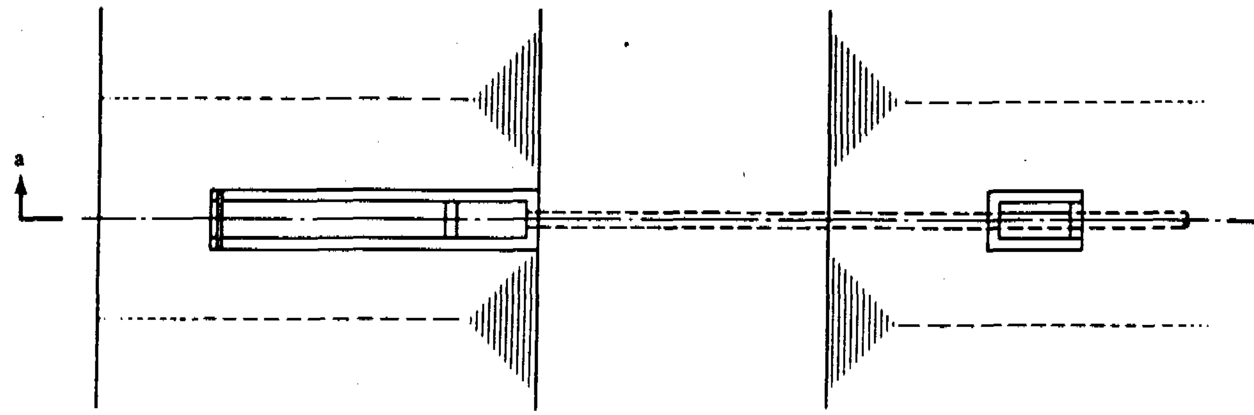
Plan



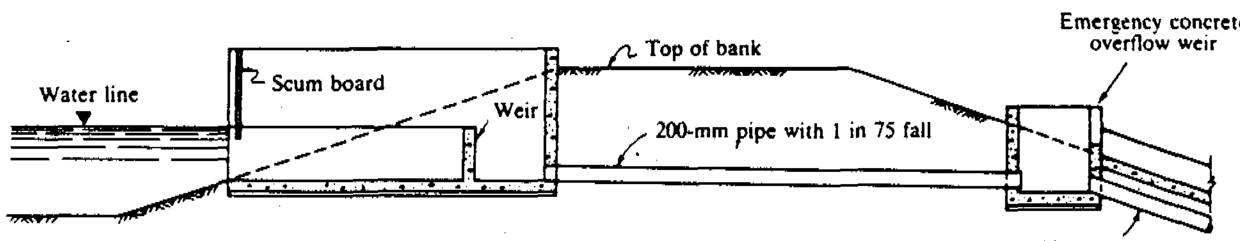
Section a-a

Inlet chute for a facultative or maturation lagoon

Fig. 36 Inlet structures for stabilization ponds

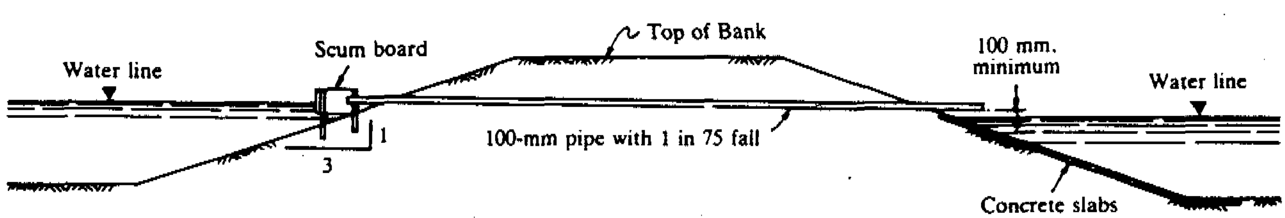


Plan



Section a-a

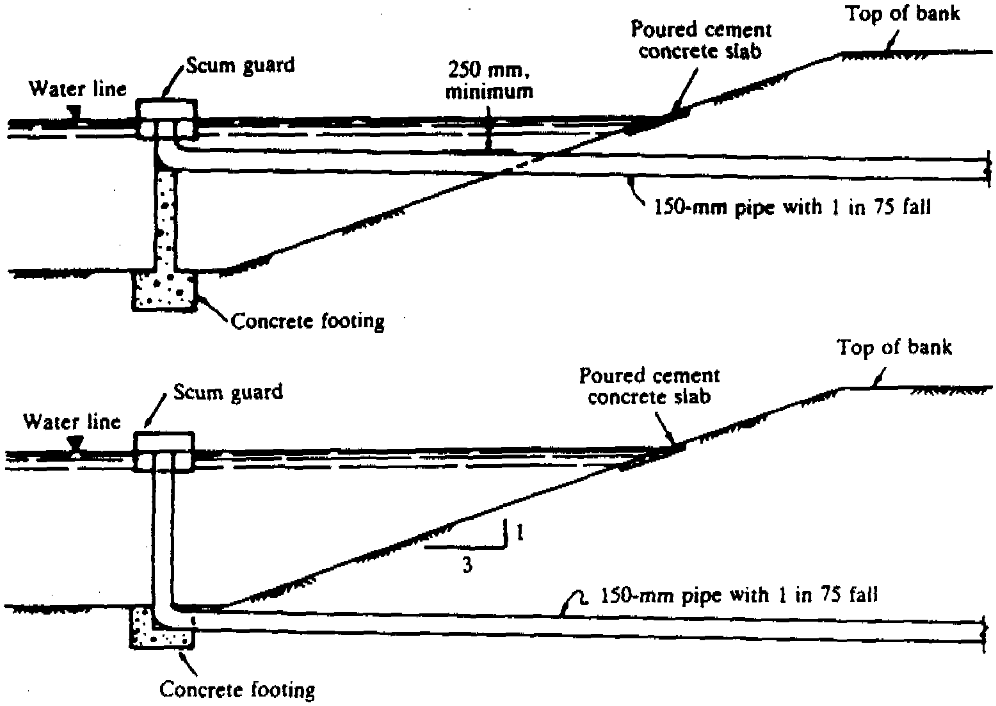
Interpond connection with concrete overflow weir



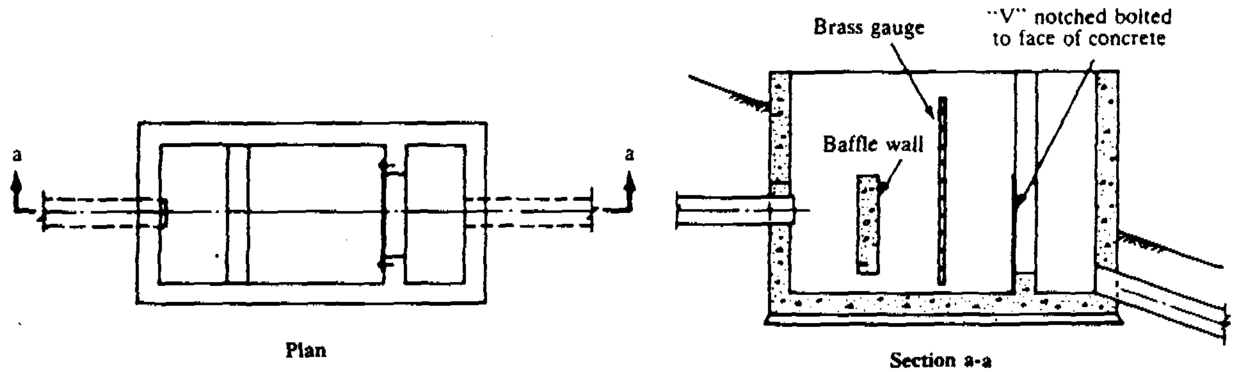
Simple interpond connection suitable for small lagoons

Note: Interpond connection, comprising a concrete overflow weir and a downstream junction chamber, would be connected to an inlet chute similar to that shown in figure 21-2.
Source: Mara (1976). ©John Wiley and Sons Ltd.; used by permission.

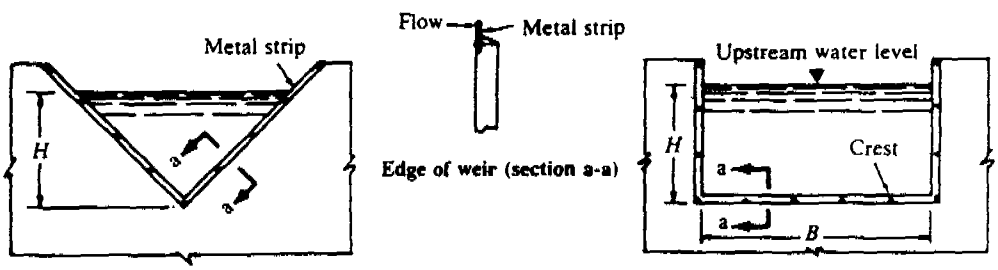
Fig. 37 Alternative interpond connections



Alternative interpond connections made from standard pipe fittings



Flow-measuring chamber for final effluent



90° triangular weir (Q, m³/sec = $1.38H^{5/2}$ **Rectangular weir (Q, m³/sec = $1.84BH^{3/2}$**

Note: Q, quantity; m³/sec, cubic meters per second; H, heights; B, breadth.
Sources: For flow-measuring chamber, Mara (1976; ©John Wiley and sons Ltd.; used by permission). For weirs, Okun and Ponghis (1975).

Fig. 38 Outlet structures for stabilization ponds

3.2.(a) Composting: When large quantities of organic wastes have to be decomposed, offsite composting should be implemented. Offsite composting employs aerobic reactions to shorten the composting period and reduce the size of composting plants. Few such composting systems currently in operation are listed below:

(i) Chinese ground-surface aerobic composting pile: As shown in Figure 39, the compost feed (a mixture of human or animal manure and vegetable matter) is piled up into a heap of approximately 2 X 2 X 0.5 m (length X width X height). The compost heap is pierced by perforated bamboo poles to facilitate natural aeration and provide a kind of structural support, and no turning of composting pile is required.

(ii) DANO system: A schematic diagram of a typical DANO plant manufactured for solid waste composting is shown in Figure 40. Materials to be composted are fed into the DANO biostabilizer, a cylindrical chamber tilted slightly from the horizontal, usually about 3 to 4 m in diameter and varying from 25 to 30 m in length according to the quantity of feeding materials.

This system was developed in Denmark which is presently being used for solid waste composting in several countries.

(iii) Forced-air aeration composting: This method called the Beltsvile aerated rapid composting (BARC) method is considered to be one of the efficient composting methods which ensures temperature in the thermophilic range and provides an inactivation of pathogens. EPSTEIN et al. (1976) developed this method and involves placing of a mixture of sludge and wood chips over a base. The schematic diagrams of an aerated pile indicating location of the aeration pipe, and showing construction and arrangement of aeration pipes using this method are shown in Figures 41 and 42 respectively.

3.2.(b) Bio-gas production: When organic wastes are digested anaerobically, a mixture of methane, carbon dioxide, and other gases is given off. This gas has become known as `biogas' and can be produced on various scales using different technologies.

Several designs for rural bio-gas plants are available. Two such designs are shown in Figure 43. The Chinese design is advantageous in that it contains no moving parts, avoids the need for a metallic gasholder, and permits the gas to be stored at a relatively constant pressure. Figures 44 through 46 represent few more bio-gas digesters which are in rapid use in developing countries.

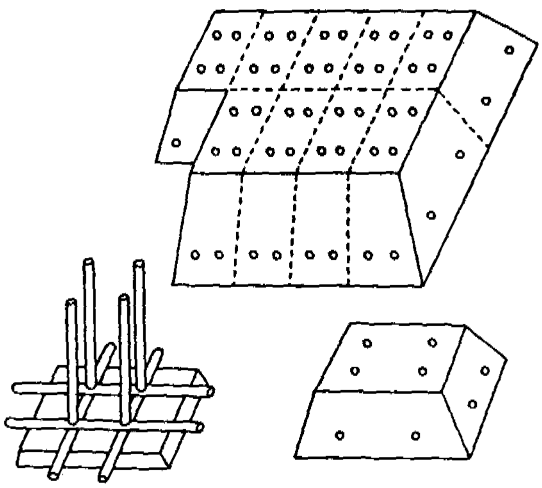


Fig. 39 Chinese ground surface aerobic composting pile (McGarry and Stainforth,1978)

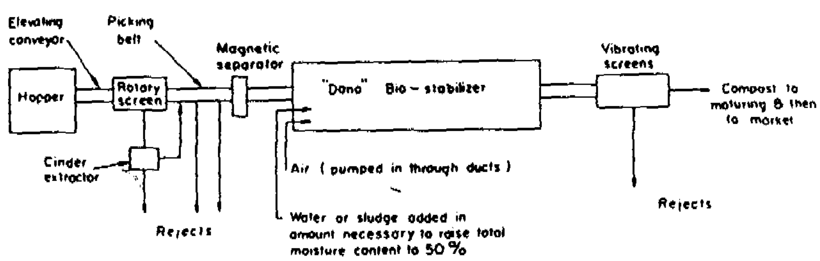


Fig. 40 Typical DANO composting plant (after Fintoff and Millard,1969)

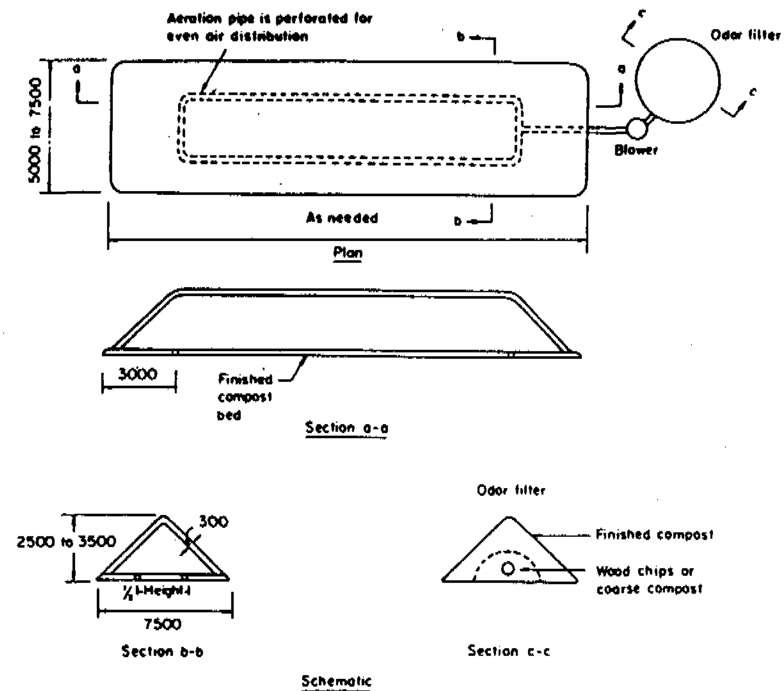


Fig. 41 Schematic diagram of an aerated pile

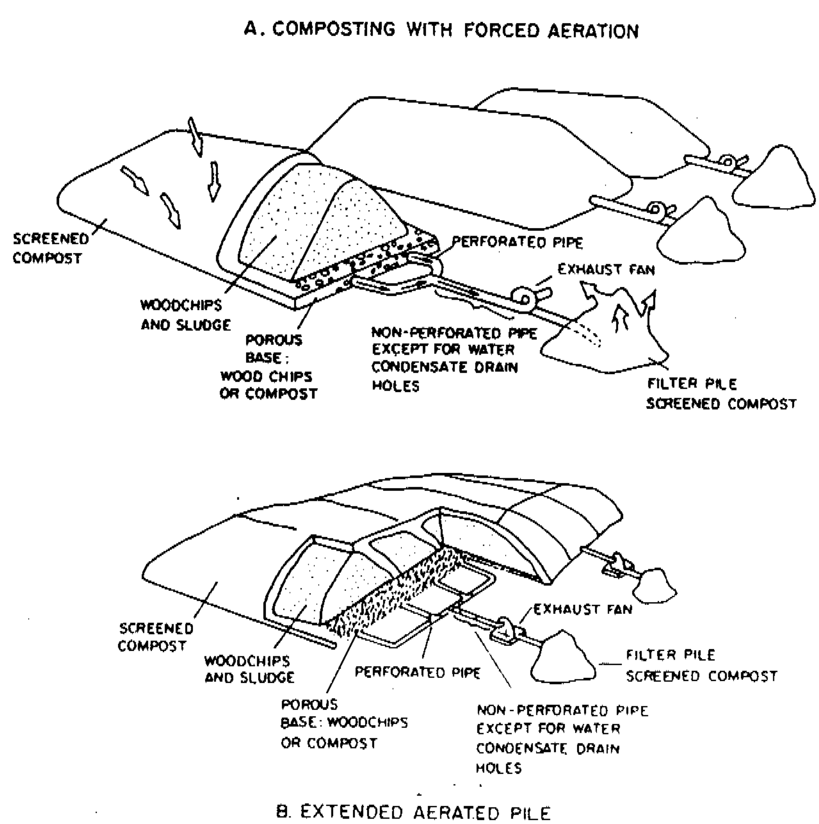
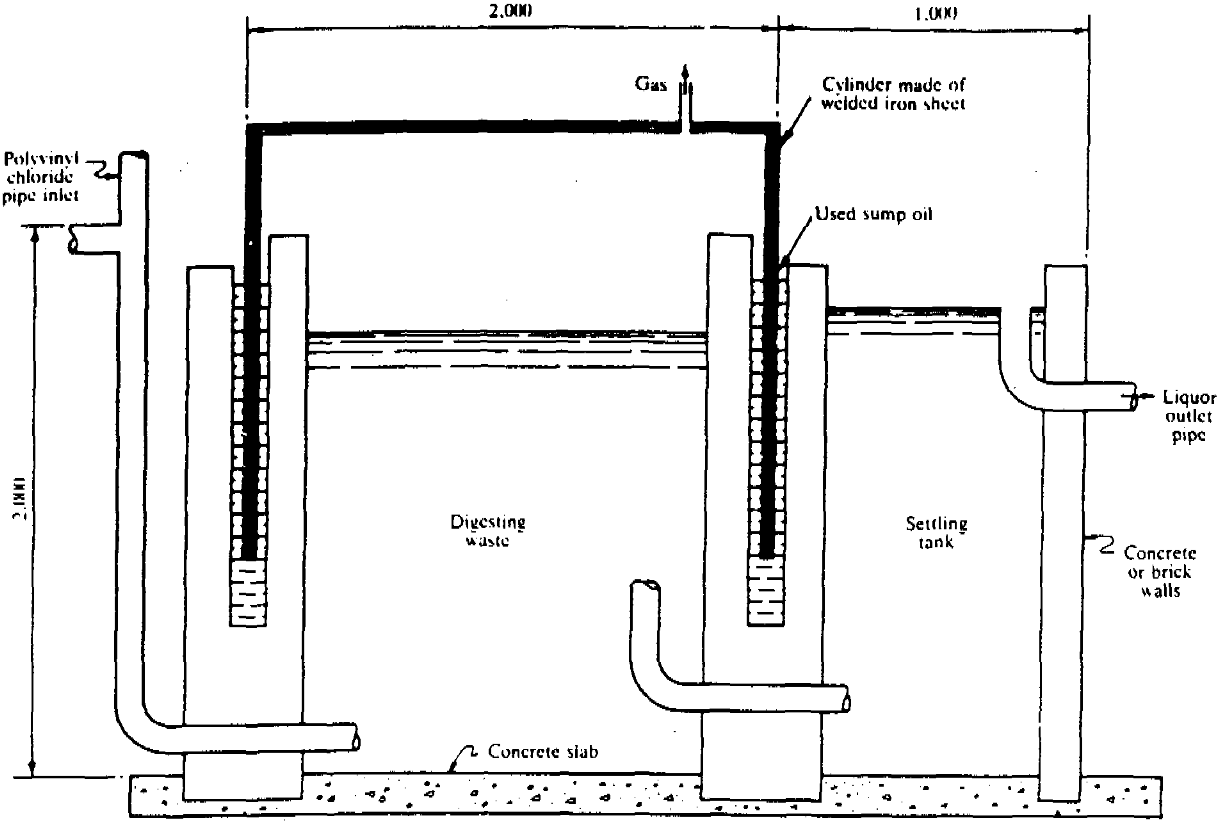
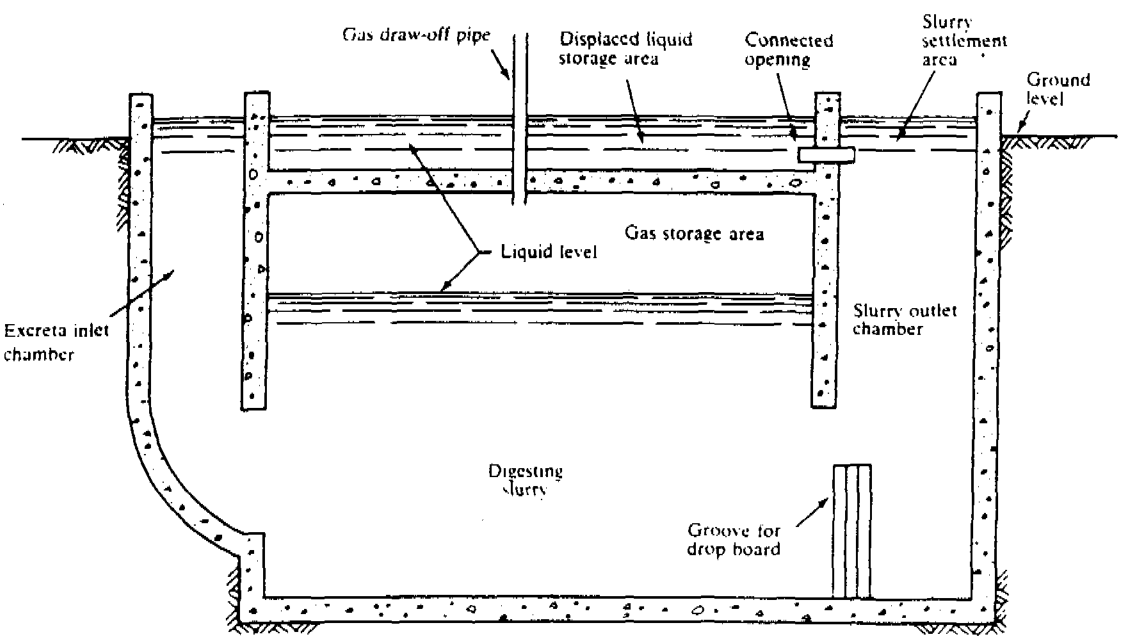


Fig. 42 Configuration of an aerated piles showing construction of pile and the arrangement of aeration pipe -the BARC system (Shuval et. al,1981)



Floating metal gasholder



Chinese design

Fig. 43 Schematic of typical biogas digesters

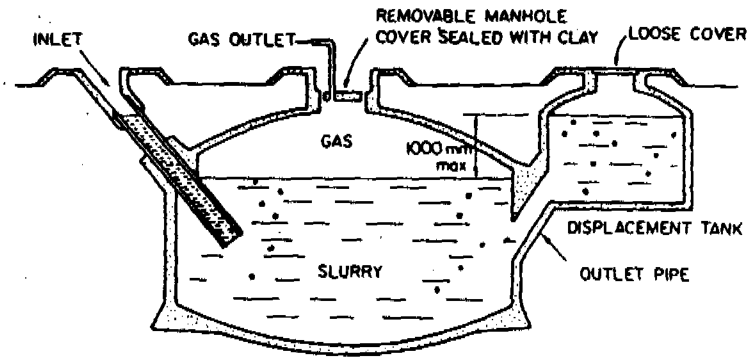


Fig. 44 (a) Fixed-dome digester

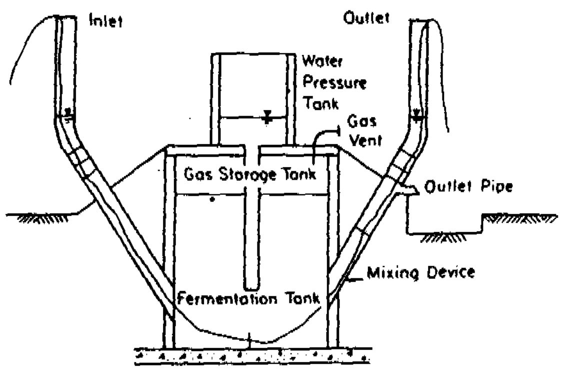


Fig. 44 (b) A low cost bio-gas digester

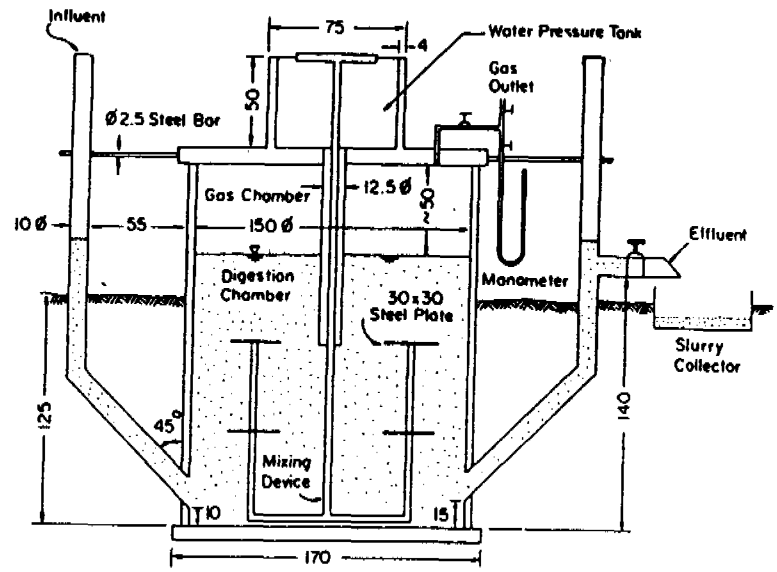


Fig. 45 (a) Pilot-scale digester (adapted from Polprasert et. al,1982)

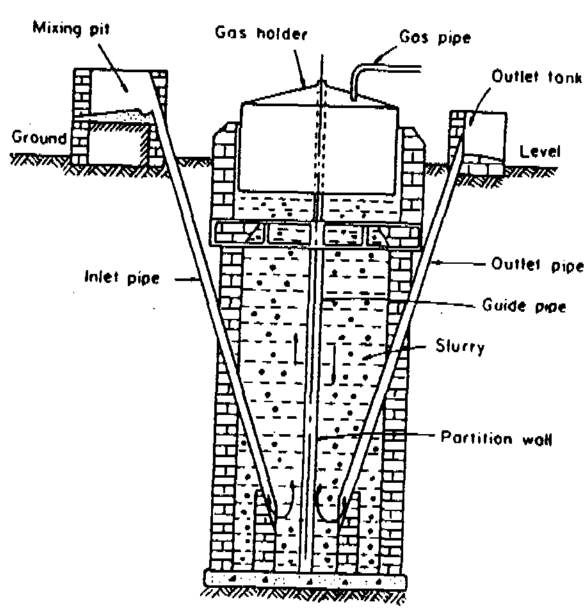


Fig. 45 (b) Operation of a floating gas holder digester

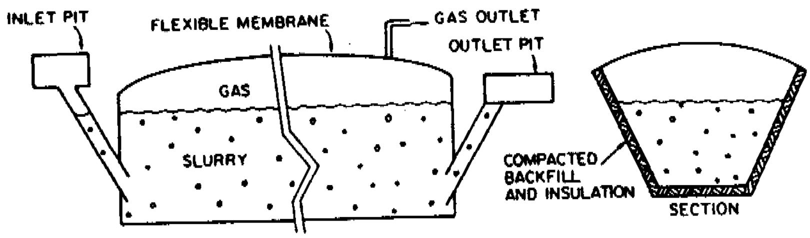


Fig. 46 (a) Plug flow digester

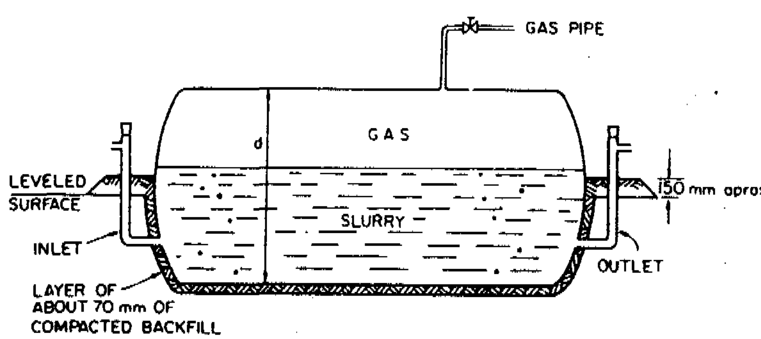


Fig. 46 (b) Bag digester

II. Water and Sanitation Related Diseases

1. Means of Disease Transmission:

Major causes of illness and death among the people in both urban and rural areas in many developing countries are the diseases related to water and sanitation. The health and wellbeing of people cannot be improved without understanding these diseases and knowing how they transmit from one person to another. Around 30 diseases are related to water and sanitation. Table 2 lists 21 such diseases under four sub-headings. Each of them are briefly explained below.

1.1. Waterborne diseases: In these diseases, the microorganisms which cause the disease are swallowed with contaminated water. However, Guniea worms, are caused by organisms found in human excreta, the source of contamination.

Cholera and typhoid fever are the waterborne diseases which are most feared; when untreated, they have high death rates. However, diarrheas and dysenteries are more important because of the infant deaths and huge numbers of illnesses they cause. The transmission of waterborne diseases is person to person. The microorganism from infected people contaminate water which is consumed by other people. Figure 47 shows a common way for the transmission of waterborne diseases.

1.2. Water-washed diseases: These are diseases whose transmission results from a lack of sufficient clean water for frequent bathing, hand washing before meals and after going to the toilet, for washing clothes and household utensils. A common way of transmission of water-washed disease is shown in Figure 48.

1.3. Water-contact diseases: These are diseases which transmitted when people have contact with infected water. The single most important water-contact disease is Schistosomiasis (blood fluke disease). This disease is very widespread in Asia, Africa and South America with hundreds of millions of people at risk of getting the disease and millions suffering from it. Figure 49 shows how schistosomiasis is transmitted. The life cycle for schistosoma species has been given later in Figure 53.

1.4. Water-related/insect vector (carrier) diseases: These are the diseases transmitted by insects which breed in or near water. Transmission occurs when the insect becomes infected with the *disease organisms from biting a person or animal, and then* bites another person. The parasites are injected into the skin or bloodstrem by the insect bite. The insects then breed in water which is used as water supply (streams and rivers) and, in case of mosquitoes, in water storage jars, and water tanks, or in shaded high humidity areas near streams and lakes. A common way of this disease transmission is presented in Figure 50.

Table 2 Water and Sanitation-Related Diseases

Category	Disease: Common name	Disease: Medical name	Type of Organism	Transmission
Waterborne (Water quality related)	Cholera Typhoid fever Paratyphoid fever Bacillary dysentery Amebic dysentery Diarrhea Diarrhea Jaundice Guinea worm	Cholera Typhoid Paratyphoid Shigellosis Amebiasis Salmonellosis Giardiasis Hepatitis Dracunculiasis	Vibrio Bacteria Bacteria Bacteria Protozoan Bacteria Protozoan Virus Worm	By consuming (drinking) fecally contaminated raw water containing an infective dose of the vibrio, bacterium, protozoan or virus; except Guinea worm where transmission is by swallowing water flea infected with worm larva that was shed from skin blister on infected human.
Water-washed (Water quantity; and accessibility related)	Bacillary dysentery Diarrhea Viral diarrhea Trachoma Pink eye Itch	Shigellosis Salmonellosis Enteroviruses Trachoma Conjunctivitis Scabies	Bacteria Bacteria Virus Intracelluar bacteria Bacteria Mite	Anal-oral or skin-to-skin direct contact transmission resulting from poor personal cleanliness and hygiene caused from lack of water for sufficient washing, bathing and cleaning.
Water-contact (Body-of-water related)	Blood fluke disease	Schistosomiasis	Worm	Eggs in feces or urine hatch larvae in water, penetrate suitable snail, multiply greatly in snail, free-swimming larvae leave snail, penetrate skin when person has contact with infected water.
Water-related insect vectors (carriers) (Water-site related)	Yellow fever Malaria Filarial fever Sleeping sickness River blindness	Yellow fever Malaria Filiariasis Trypanosomiasis Onchocerciasis	Virus Protozoa Worm Protozoa Worm	Mosquitoes, tsetse flies and blackflies, which breed in or near water, pick up disease organisms when they bite infected person; organisms grow in vectors and are inoculated into another person when insect bites.
Sanitation-related (Fecal polluted soil related)	Hookworm Roundworm	Ancylostomiasis Ascariasis	Worm Worm	Eggs or larvae become infective when feces are deposited on soil; eggs are eaten from contaminated hands or vegetables, or larvae penetrate skin that comes in contact with infected soil.

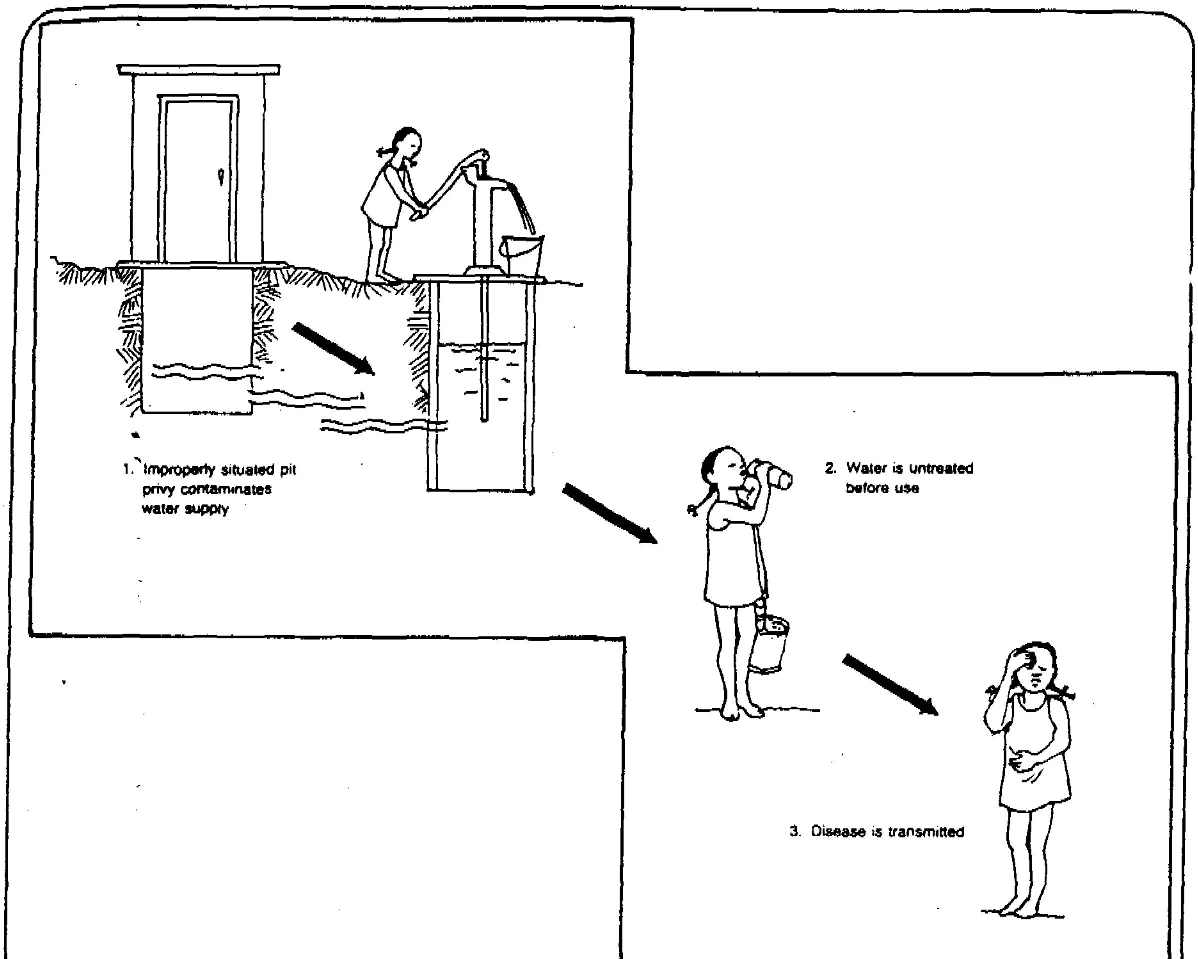


Fig. 47 Transmission of Waterborne Disease

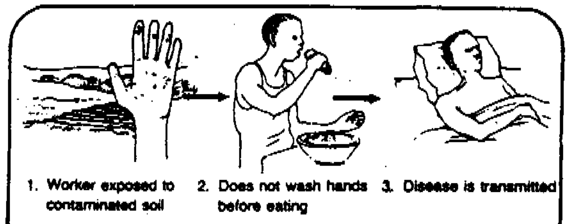


Fig. 48 Transmission of Water-Washed Diseases

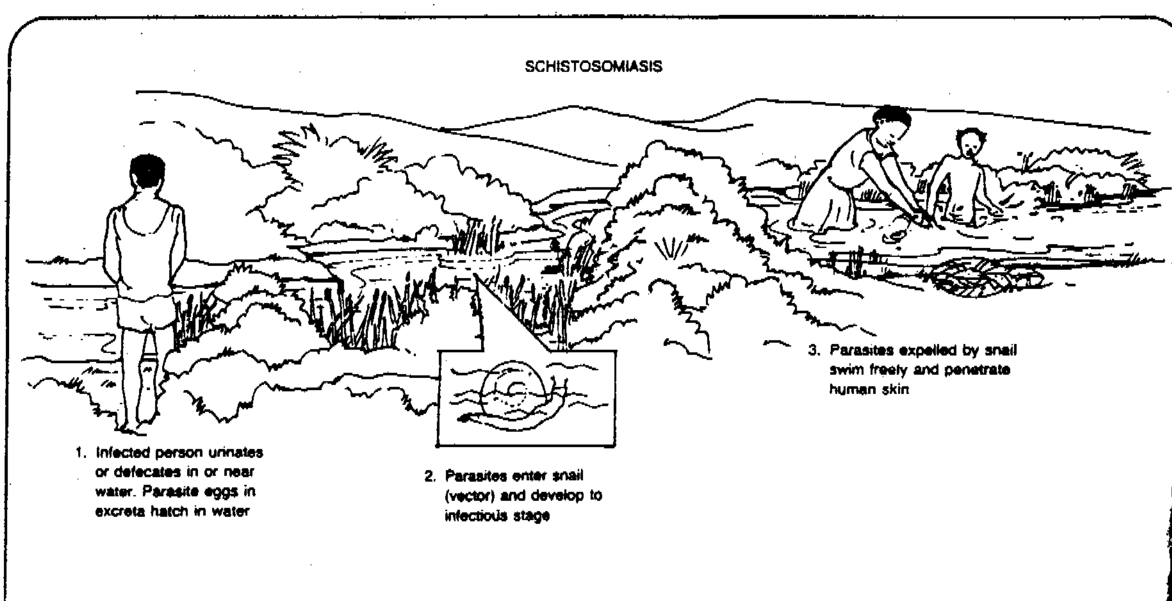


Fig. 49 Transmission of Water-Based/Water-Contact Diseases

1.5. __Sanitation-related diseases__: These are diseases which are transmitted by people lacking both sanitary facilities for waste disposal and knowledge of the need to dispose of wastes in a sanitary manner. The infective stage of the worm which causes these diseases develops in fecally contaminated soil. Hookworms and roundworms are the most common diseases of this category. Transmission of these diseases are shown in Figure 51.

Figures 52 through 58 represent few examples of the life cycles of diseases. Details on them can be found in any standard text book dealing with environmental health and sanitation.

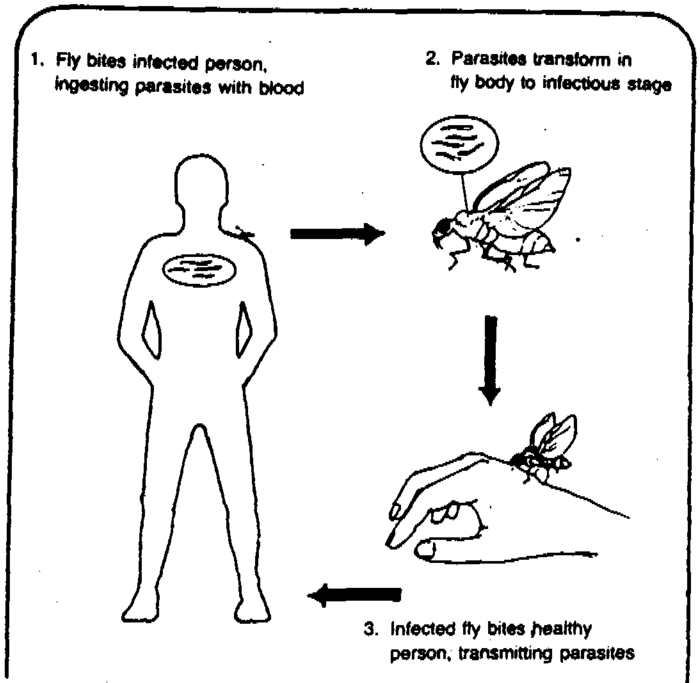


Fig. 50 Transmission of Water-Related (Insect Carried) Diseases

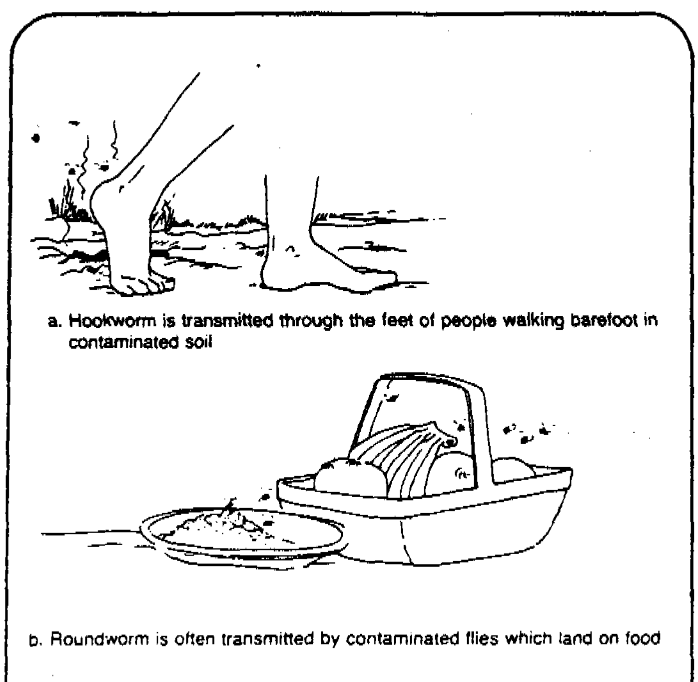


Fig. 51 Transmission of Sanitation-Related Diseases

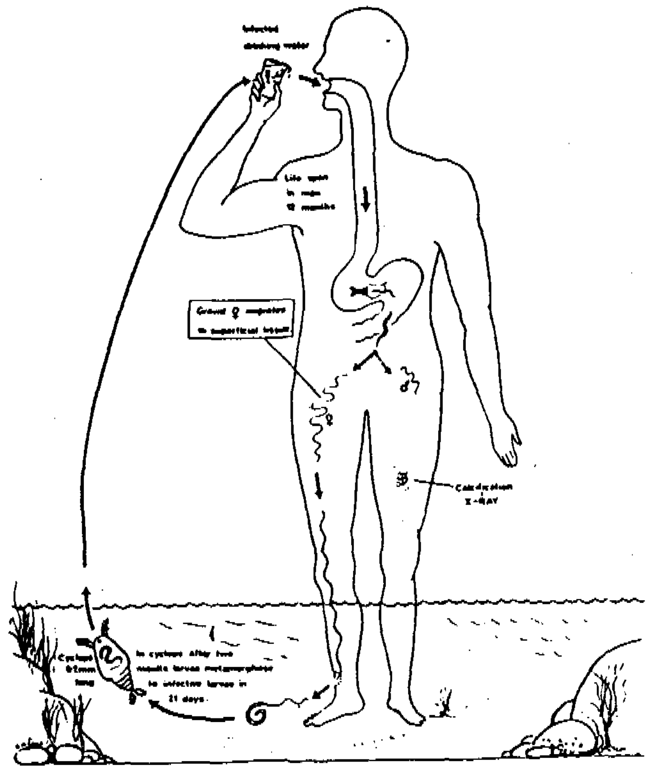


Figure D3 The life cycle of *Dracunculus medinensis* (the Guinea worm)
Source: From Jeffrey and Leach (1975). Reproduced by permission of Churchill Livingstone

Fig. 52 (a) The life cycle of Dracunculus medinensis (the Guinea worm, Waterborne disease)

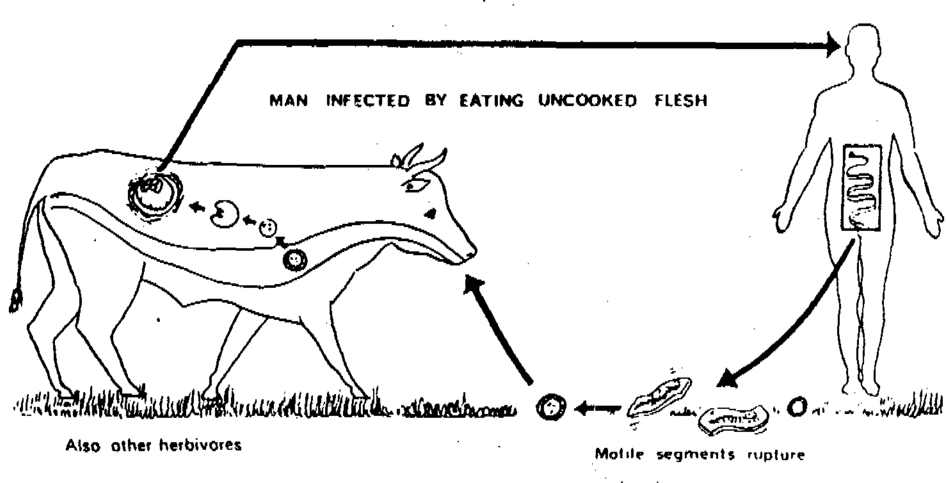


Fig. 52 (b) The life cycle of Taenia saginata (the beef-tapeworm, Water-related disease)

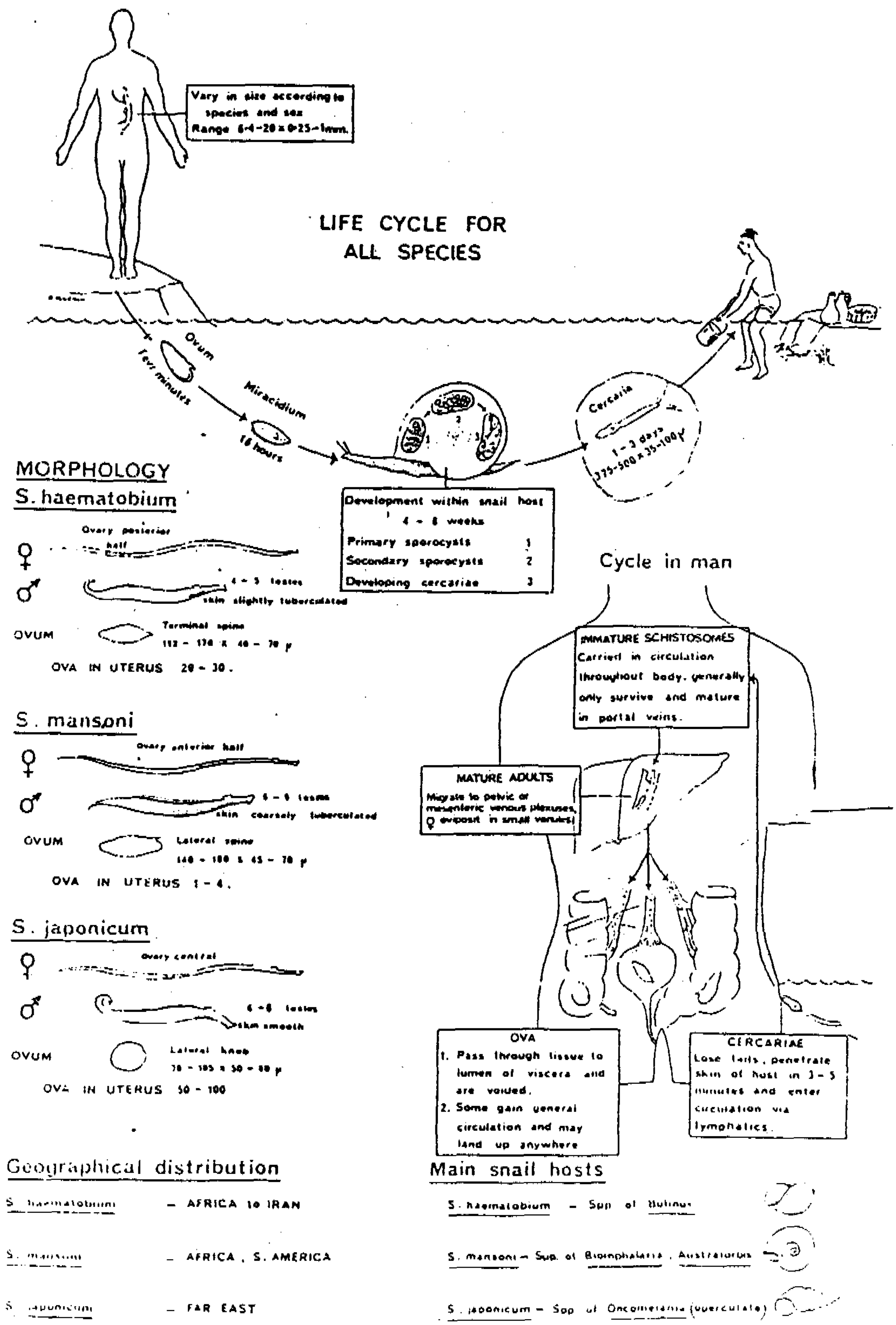
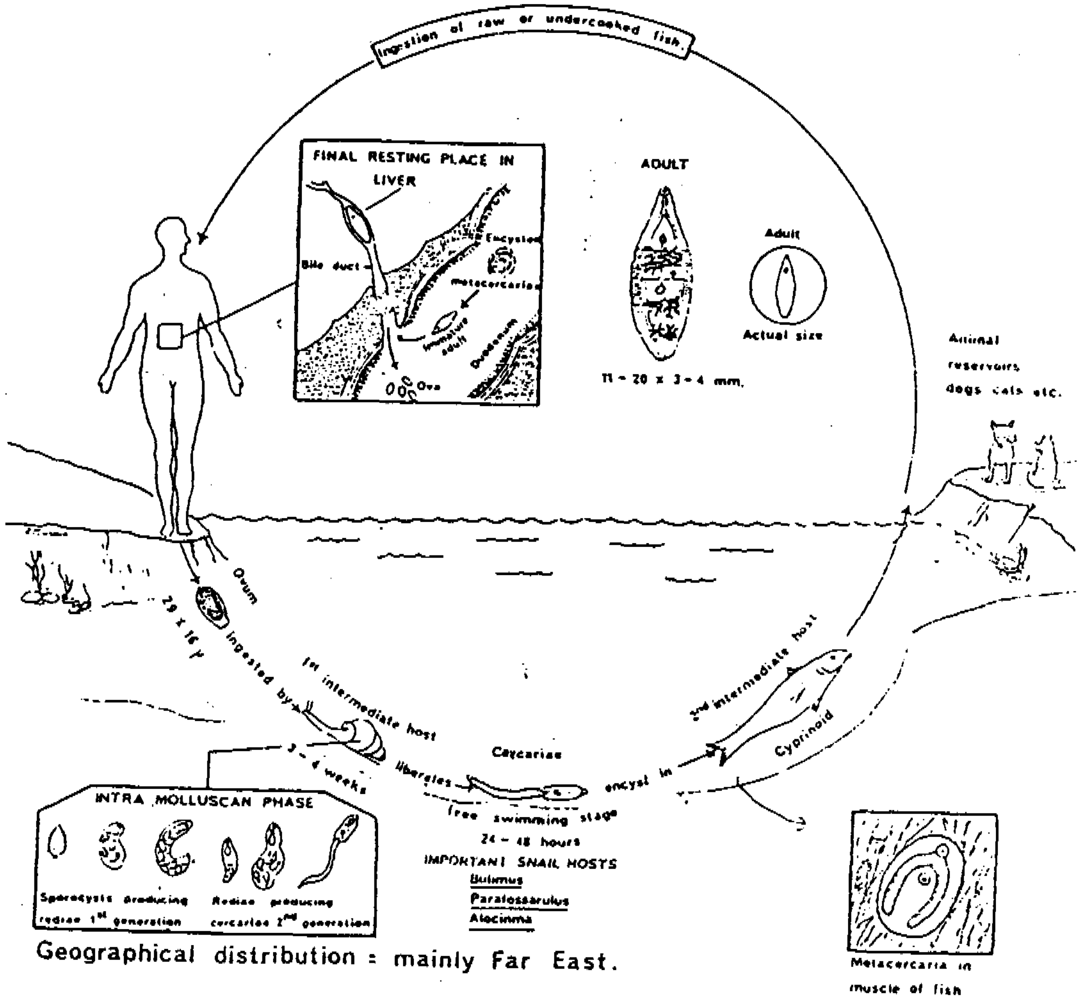


Fig. 53 Schistosoma species (The blood fluke, Water-contact disease)

Clonorchis sinensis



Geographical distribution = mainly Far East.

PATHOLOGY.

Adults inhabit distal bile ducts with -

1. Epithelial proliferation.
2. Surrounding inflammatory reaction.
3. Sometimes secondary infection.
4. Eosinophilia.

Leading to -

1. Thick, dilated fibrous ducts with adenomata of epithelium.
2. Cirrhosis and destruction of liver parenchyma.
3. Portal hypertension with splenomegaly.

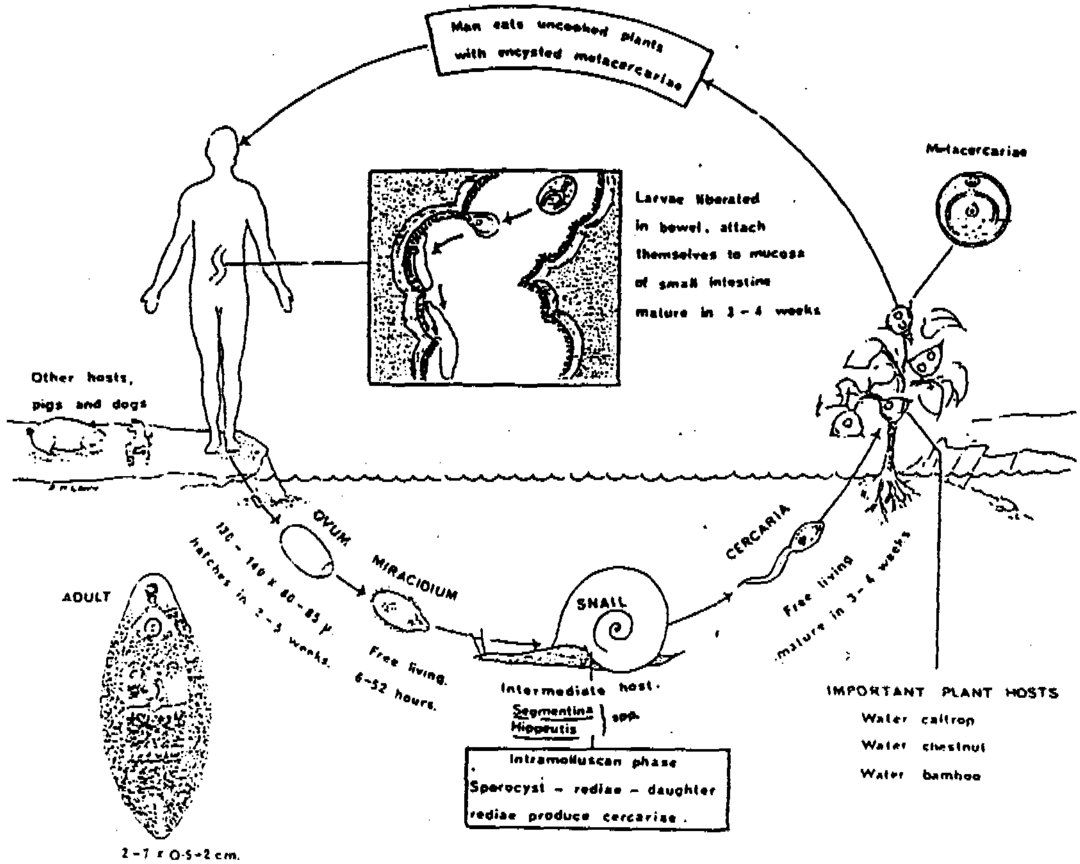
Occasionally pancreatic ducts invaded with similar changes in pancreas.

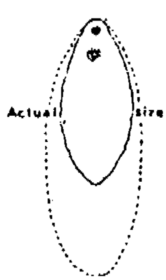
LABORATORY DIAGNOSIS

OVA In faeces
In bile (by duodenal tube)

Fig. 54 Clonorchis sinensis (Chinese liver fluke, water-contact disease)

Fasciolopsis buski





Geographical distribution : Far East

PATHOLOGY

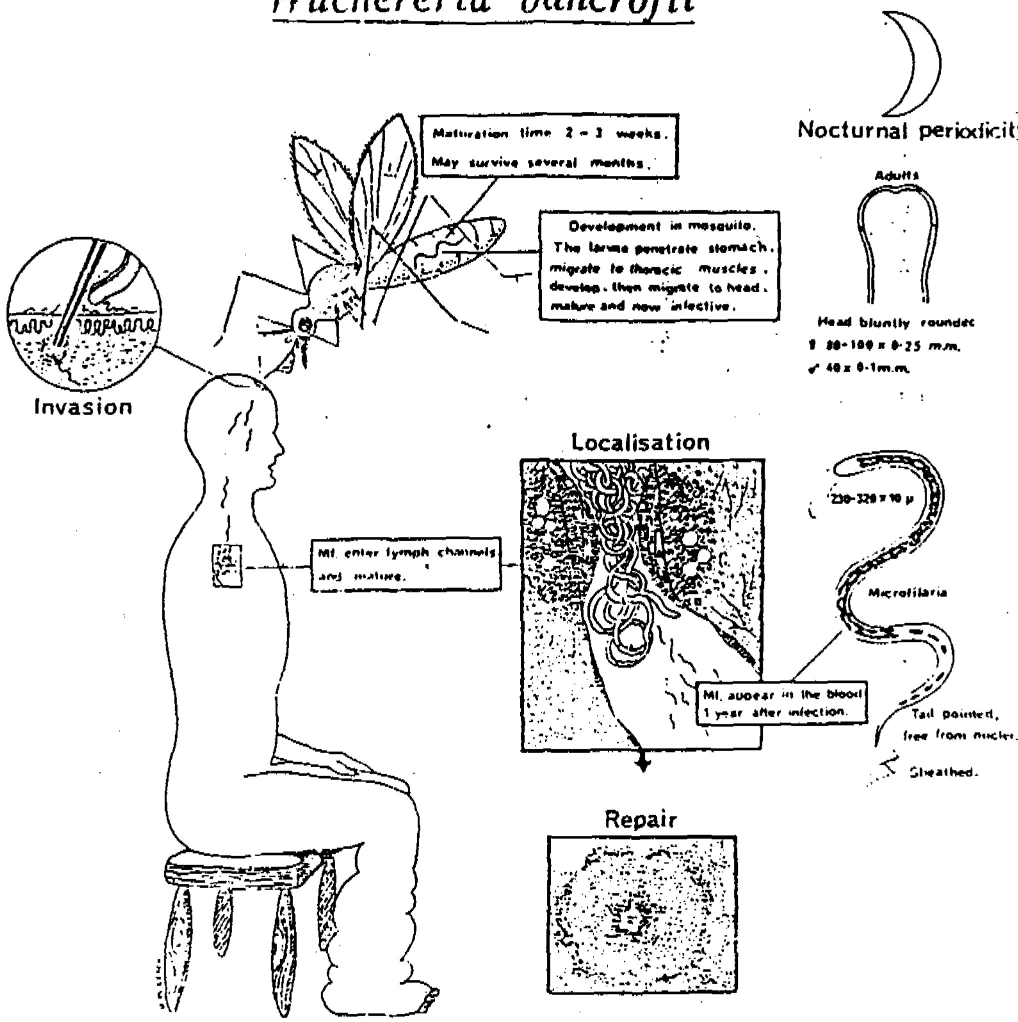
Localised inflammation at site of attachment with haemorrhages, abscesses sometimes. Eosinophilia.

LABORATORY DIAGNOSIS

Ova, sometimes adults, in faeces.
C F T (Cross reaction with F. hepatica.)

Fig. 55 Fasciolopsis buski (Giant intestinal fluke, Water-contact disease)

Wuchereria bancrofti



Geographical distribution : Asia, Africa, S. America, Australasia.

PATHOLOGY.

Adults in lymphatic channels cause –

1. Proliferation of lining endothelium.
2. Surrounding infiltration of

Eosinophils		Obstruction	Lymph varices
Macrophages	Filarial granulation	Secondary infection	Lymphadenopathy
Lymphocytes	tissue leading to	Fibrosis	Elephantiasis
Giant cells		Calcification	Hydrocele, Chyluria etc.

LABORATORY DIAGNOSIS.

1. Microfilariae in thick blood film (10 pm – 2 am) stained, unstained (centrifuge concentration). Chylous exudate or chylous urine.
2. Histological examination of biopsy material
3. Intradermal test with dirofilarial antigen (only group – specific).

Fig. 56 Wuchereria bancrofti (Filariasis, Water-related disease)

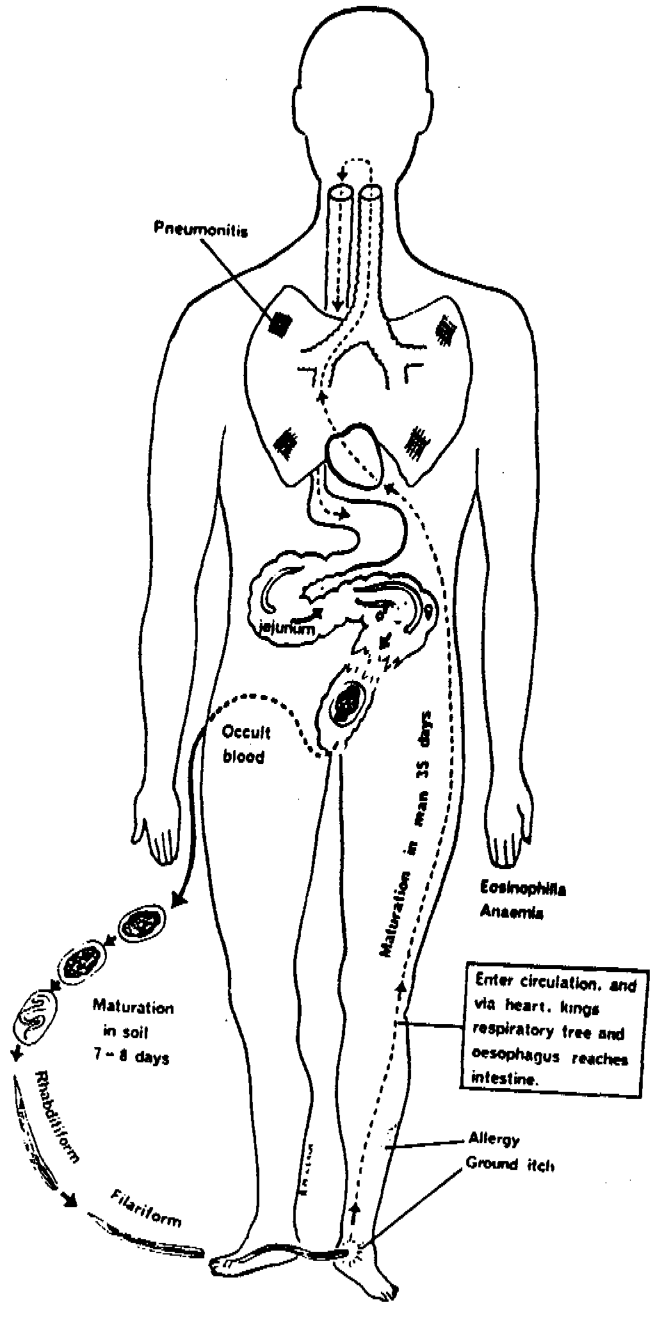


Fig. 57 Hookworm (Sanitation-related disease)

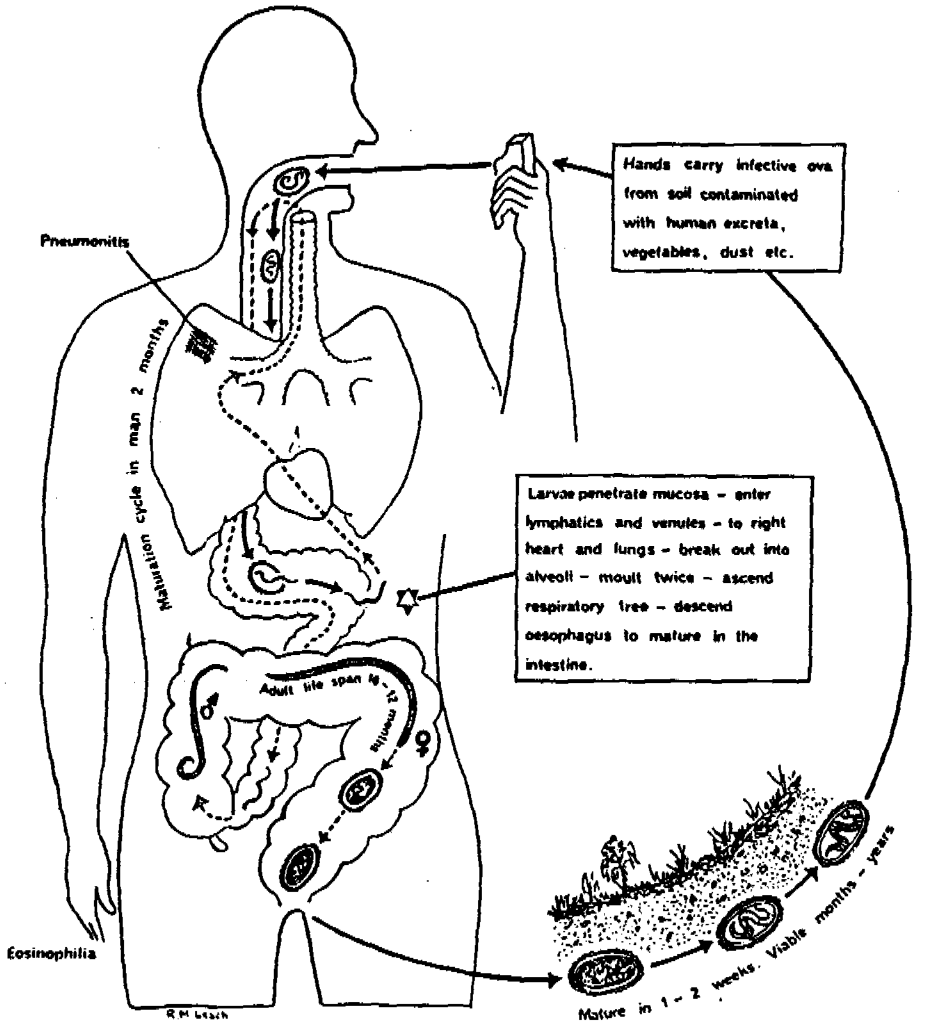


Fig. 58 Roundworm (Sanitation-related disease)

2. Methods for Improving Environmental Health Conditions:

The improvement of people's health may require that certain changes be made in the environment. Local conditions that contribute to the transmission of diseases must be eliminated. Water supplies have to be protected, treated, or improved. Proper methods for sanitary disposal of wastes must be used, insect vectors must be controlled, destroyed, and educational programs must be instituted to make people aware of the need to prevent disease .and teach them how to do so. A brief description of the prevention of water and sanitation-related diseases under different headings are presented as follows:

2.1. Waterborne diseases: Several methods of preventing water contamination and improving the quality of water can be used. The most important measures for improving local environmental conditions are:

- Insure that people have and use sanitary latrines.

- Educate people so that they know where to locate latrines and how to construct them properly. All latrines should be located at least 15 meter away from the nearest source of water. Figure 59 is an example for proper the location of an aquaprivy.

- Ensure that the pit does not puncture an aquifer. Latrine seepage that enters an aquifer can contaminate ground water (wells) and spring water supplies.

- Protect all wells and springs against contamination from surface run off (Figure 60). Cap springs with spring boxes. Finish wells with a well head such that no surface water should seep into wells.

- For surface sources, especially those providing large quantities of water, set up an intake that allows for filtration and other purifying mechanisms like chlorination of water before it enters storage.

- Dispose garbage and animal manure properly in a sanitary manner for controlling the breeding of flies, and cover latrine openings tightly when not in use (Figure 61).

2.2. Water-washed diseases: These diseases can be prevented by the provision of sufficient quantities of safe water. People should be educated and motivated to practice personal and family hygiene. Washing of the hands and bathing in clean water are most important. Clothes and dishes should be washed to ensure that skin diseases are not passed to people by contaminated hands, clothing or utensils.

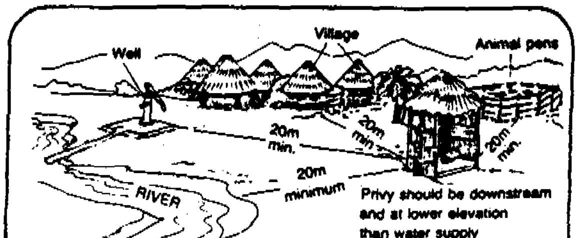


Fig. 59 Proper Location of Privy

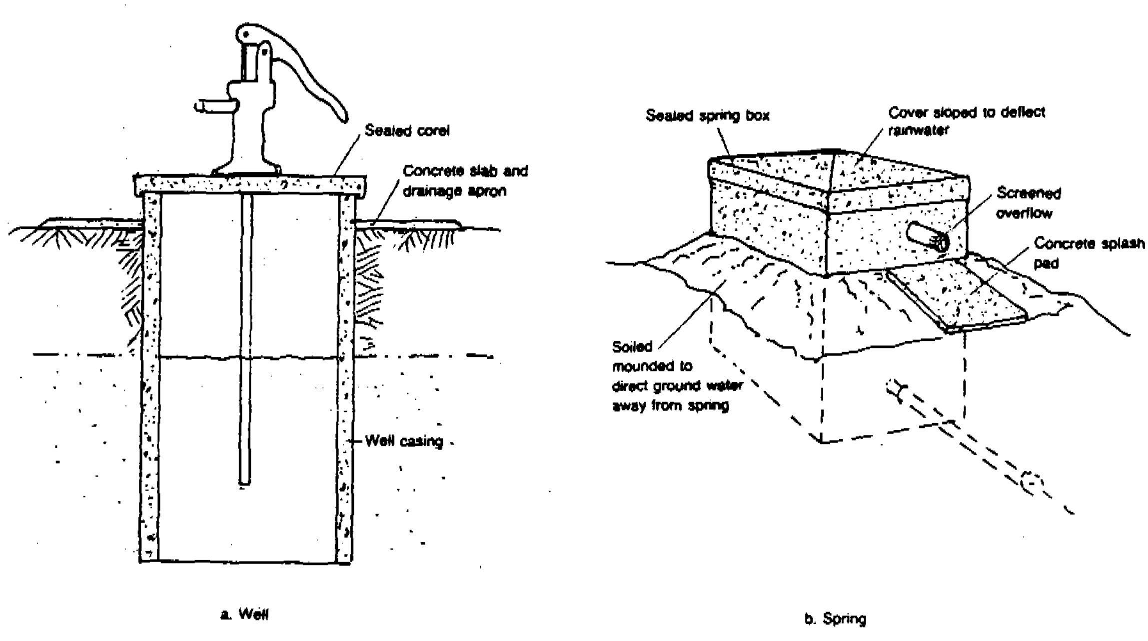


Fig. 60 Proper Protection of Water Supplies

2.3. <u>Water-contact diseases</u>: These diseases can be controlled by both chemical and environmental means. The major disease in this category is Schistosomiasis. This disease can be controlled by breaking the chain of transmission at several points. The following measures are advantageous in controlling the spread of schistosomiasis:

- Encourage people to build sanitary facilities and use them properly, and the eggs in the feces and urine will die, preventing the infection of the snails if they do not reach the water body. Use snails killing chemicals in the drainage ditches regularly, and when canals are built, line them with a smooth surface like concrete and provide for a rapid flow rate.

- Maintain the banks of all irrigation canals and bodies of water such that vegetation and weeds are kept away from the canal and also from beach areas (Figure 62).

2.4. <u>Water-related insect vectors</u>: Disease control under this heading involves the elimination of mosquitoes and flies through environmental or chemical means. Although the applications of both aerial and ground spraying of insecticides have proved very effective, there are questions about environmental effects of using them on a large scale for a long time. Chemical control is sure to continue, but other methods should also be incorporated into the vector control plan.

Figure 63 shows some individual preventive measures. These measures coupled with spraying and a program of health, education will greatly help reduce the growth of the mosquito and other insect populations.

2.5. <u>Sanitation-related diseases</u>: Diseases in this category, such as the hookworm and roundworm are the direct results of fecal pollution of the soil which is due to the lack of proper knowledge on good hygiene practices. These diseases can be controlled by relatively simple environmental improvements, such as:

- Education to the people on the need to use latrines and training to the children to use them at the very early age.

- Proper coverage of latrines to cover insects from breeding in the latrine pits.

- Provision for sufficient quantities of water to ensure that people can practice personal hygiene.

- Control of flies by proper means.

- Restriction of animals from entering the houses and from coming into close contact with young children (feces from animals can also spread disease).

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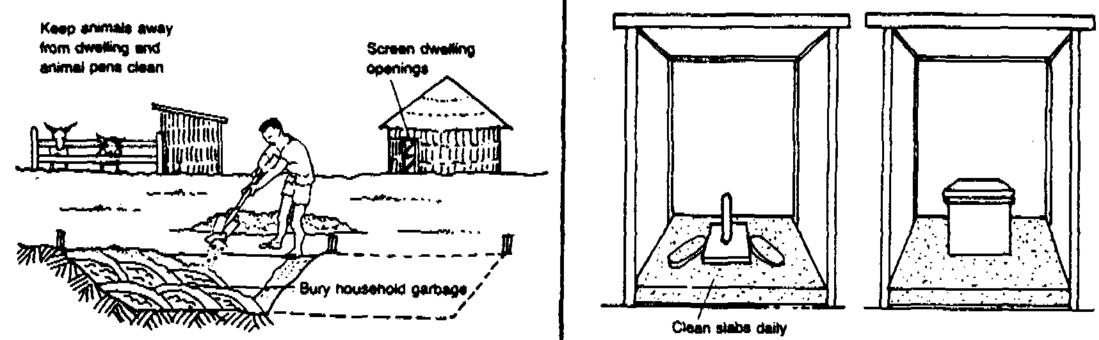

a. Control the Breeding of Flies

b. Cover Latrine Openings Tightly

Fig. 61 Proper Disposal of Wastes

Fig. 62 Chemical and Environmental Control of Schistosomiasis

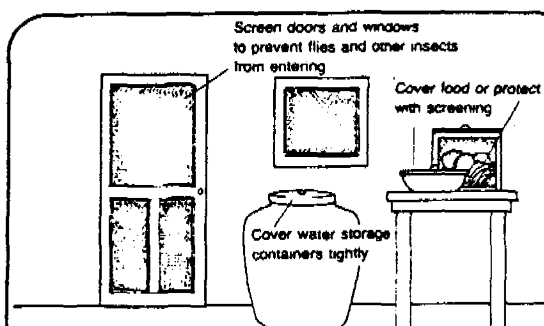

Fig. 63 Individual Preventive Measures