Choosing an on-site unsewered sanitation system

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CHOOSING AN ON-SITE UNSEWERED SANITATION SYSTEM

by

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A Masters Thesis

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STATEMENT OF RESPONSIBILITY AND ORIGINALITY

This thesis is based on a literature search. Whilst the author is responsible for the conclusions and recommendations drawn from the search he cannot be liable for the validity of the original data.

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INTRODUCTION

In 1977 it was estimated that only 32% of the population of developing countries had adequate sanitation.[1] A low level of general sanitation encourages a high level of disease within the society and this leads to low productivity, poverty and hinders development. Admittedly excreta facilities alone will not markedly reduce disease and poverty but neither will the provision of other essential services such as water supply and better housing without the addition of sanitation.

The reasons for inadequate sanitation are numerous but they may be broadly classified as educational and monetary. Poor education, in its broadest sense, means there is little pressure on governments to improve sanitation since its importance is not recognised by the community. Furthermore, there is often a lack of skilled personnel to implement and operate any scheme that is requested. Monetary constraints are a worldwide problem but they are much greater in developing countries where demands are more pressing and money supplies limited.

Developing countries that have expended some of their resources on sanitation have frequently done so unwisely, investing in conventional water borne sewerage which is expensive to install and maintain and often inappropriate. The installation of inappropriate systems is partly due to a lack of knowledge of alternative methods but also because of the desire of many governments to emulate developed countries and install "modern systems".

Fortunately pressure is now being put on governments to consider alternative forms of sanitation but knowledge about such systems is still difficult to obtain, especially in the countries where it would be of most use. This is a great shame because many of the alternative methods of sanitation are cheaper than conventional methods and simpler to implement and maintain.

The detailed information that does exist on alternative forms of sanitation is widely dispersed and often difficult to obtain. However attempts are now being made by various international bodies and individuals to collect all the relevant material together so that it may be easily disseminated.

Most of the information that is presently available covers the design of alternative systems but very little of it assists in the choosing of the most appropriate system for any given situation. It was therefore decided to try and obtain this information and present it in such a form, that given information about any particular site, it would be possible to determine the most appropriate sanitary system for it.

It was decided to restrict the research to on site, unsewered sanitary systems, since these are the main alternatives to conventional sanitation. Other alternatives such as septic tanks or communal toilets were excluded because of lack of resources and their limited scope. Where other systems might be considered however, reference is made to them in the text.

Information on the subject was obtained by carrying out a literature search. Only original reports of observations on working systems were used as far as possible and the results of these observations are summarised and discussed in the light of the author's experience of work in developing countries.

The conditions that govern the choice of a sanitary system can be divided into two categories; physical and socio-economic.

The physical conditions are such things as population density, ground conditions, climate etc. They are independent of the nature of the society and therefore their effect on the choice of any sanitary system can be defined.

Socio-economic conditions are such things as capital and running costs, social acceptability, available local materials, etc. These types of condition are dependent on the society under consideration. They cannot be evaluated beforehand as their relative importance will vary from place to place. They are conditions that do not physically control the acceptability of a system but for social reasons make one system more suitable than another.

This report is divided into three parts: two sections and an appendix.

Section 1. Information on sanitary systems: each sanitary system is taken in turn and every factor governing its choice and operation is individually discussed. All the relevant information on each factor is given and then followed by a discussion and, where appropriate, recommendations.

Section 2. Choosing a sanitary system: the information obtained in Section 1 is presented in tabular form and a method suggested for choosing the most appropriate system for any particular site.

Appendix. Auxiliary information: this section contains information that will assist in choosing the correct sanitary system. It has been given separately because it is applicable to a number of the systems discussed or is peripheral to the main object of the report.

The report does not give information on the design, construction or operation of the systems except where it affects the conditions under which the system can work. However, in each chapter there is a list of references where such details can be found.

Reference

1. World Bank, 1978. Appropriate sanitation alternatives, a technical and economic appraisal. Vol.1, Energy, Water and Telecommunications Dept. Final draft.

Object of the Report

The object of the report is fourfold.

1. To determine the factors that govern the choice of an appropriate sewage disposal system.
2. To find out what unsewered sanitation systems are available.
3. To determine the site conditions in which each system could operate.
4. Present the results of the research in such a way that knowing the particulars of any site the most appropriate system can be easily identified.

SECTION 1: INFORMATION ON SANITARY SYSTEMS

1.0 PIT LATRINES

1.1 Introduction

The pit latrine is used almost everywhere in the world; it is simple in design, easy to use and operate and can be built cheaply in any part of the world by the family with little or no outside help.

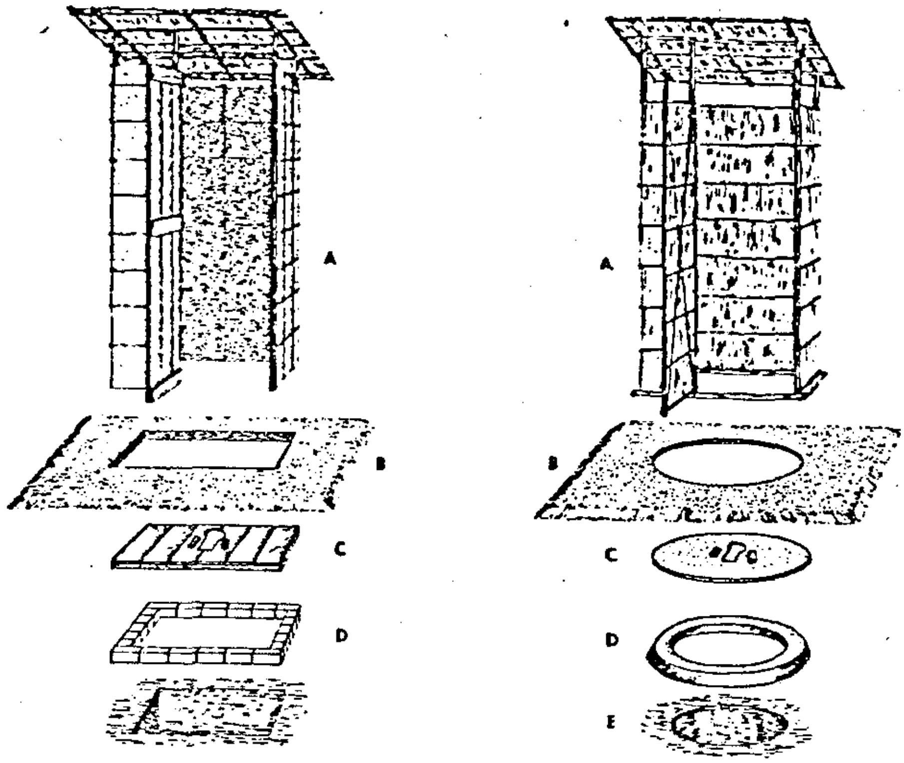
It consists basically of a hole in the ground covered with either a squatting plate or a slab provided with a riser and seat. A ventilation pipe fits into the floor slabs and a house is built to provide privacy and protection.

The pit is usually hand dug and large enough to provide a storage of human faeces and possibly refuse and sullage for 10 to 15 years. When the pit is full the superstructure is moved to another pit and the old one is filled to ground level with soil. The pit may, at a later date, be re-excavated and reused, and the contents used as a soil conditioner.

In the standard pit latrine (Fig. 1) the squatting plate is located directly over the hole but there are some variations where this is not so.

The P.R.A.I. latrine (Fig. 2) has a pit with the superstructure located to one side of it. The two are connected by a short length of pipe and the excreta and urine are flushed along the pipe into the pit by a small quantity of water. The pit top is sealed and the latrine is fitted with a water seal so there is no problem with faecal odour or flies.

The R.O.E.C. latrine (Fig. 3) also has an offset pit but the two are connected by a large diameter chute. The user sits or squats on top of the chute and the excreta slides into the pit. Odours and fly



A = House B = Mound C = Floor D = Base E = Pit

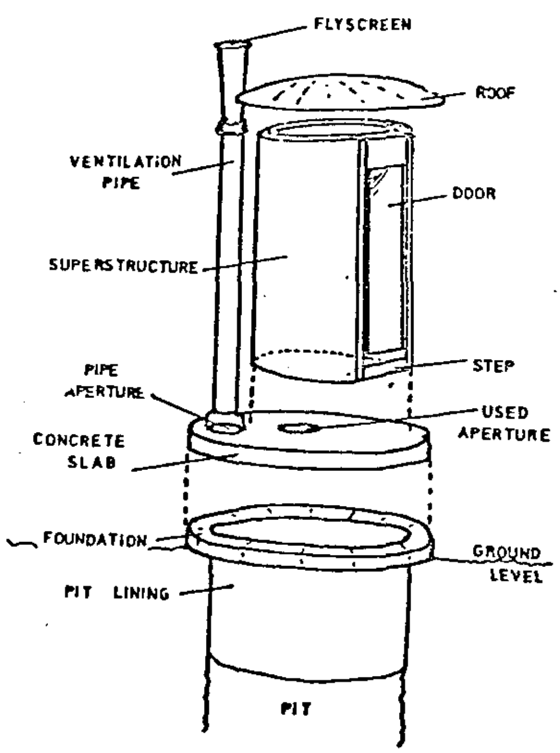


Fig. I. EXPLODED DIAGRAMS OF THREE STYLES OF PIT LATRINES

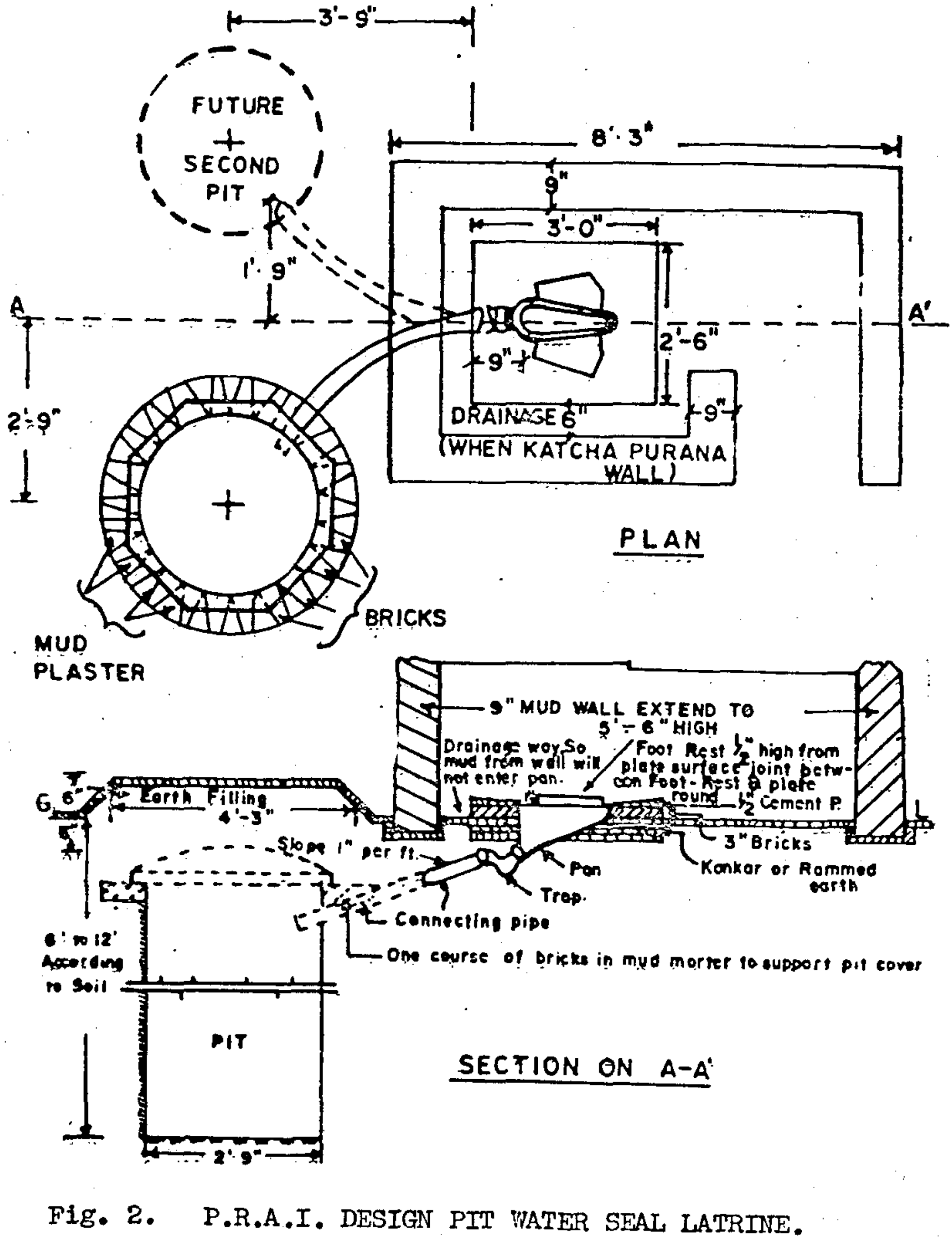


Fig. 2. P.R.A.I. DESIGN PIT WATER SEAL LATRINE.

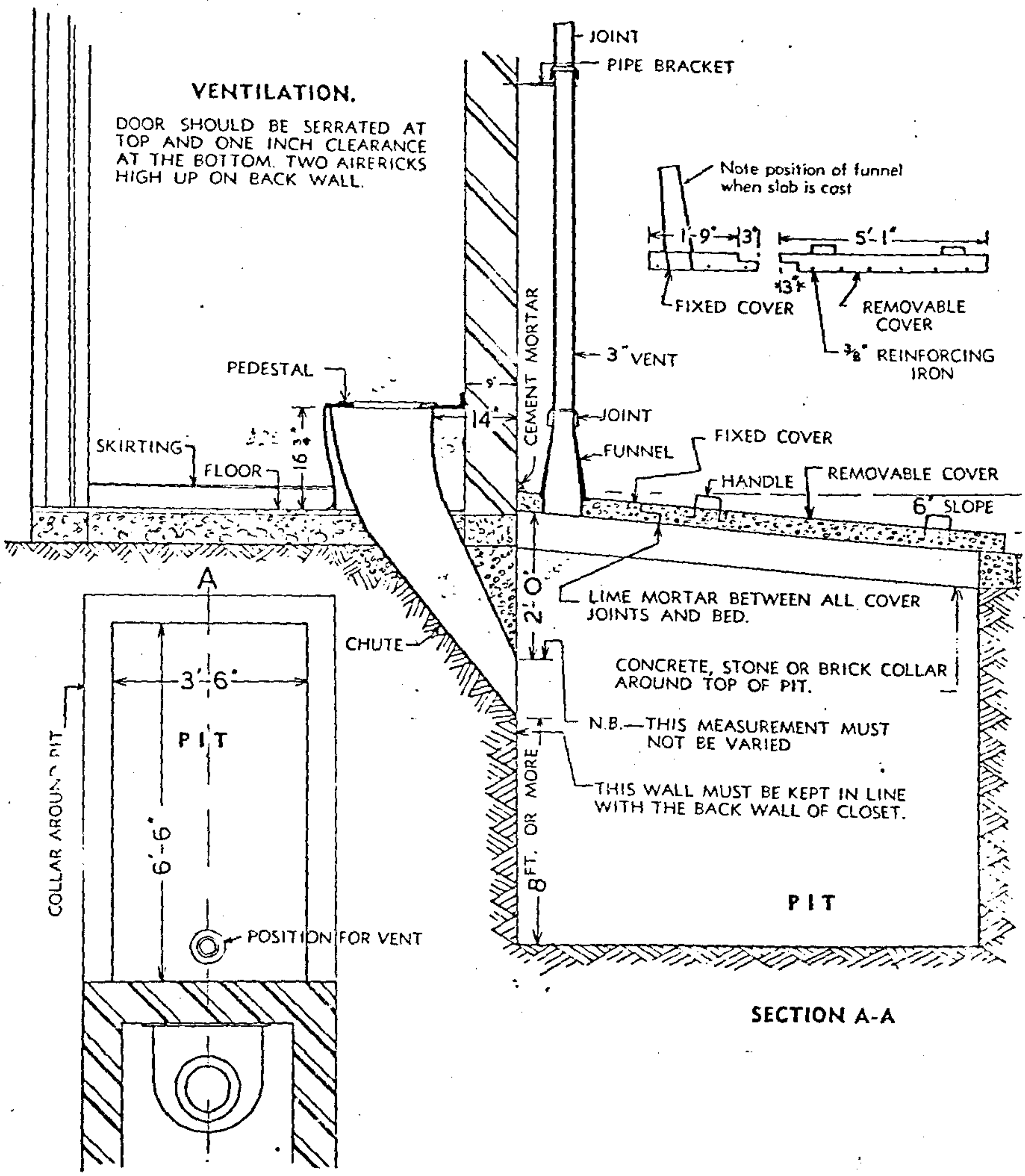


Fig. 3. R.O.E.C. DESIGN OFFSET PIT LATRINE.

problems are prevented by providing a flow of air down the chute, through the pit and up a ventilation pipe.

1.2 References for Design and Construction Details

Wagner and Lanoix[1], Boparai and Varma[2], Morgan[7], Bhaskaran[4], Blair Res. Laboratory[18], Bell's Asbestos Co.[15], U.S. Pub. Health Report No.108 [19].

1.3 Terrain and Ground Conditions

1.3.1 References

Wagner and Lanoix[1]: Pit latrines should be sited on well drained ground, above flood level. They may be excavated in any type of ground except fissured rock and limestone. Ground conditions will, however, affect the pit design.

Blackmore et al[3]: Existing pits in Botswana subside due to erosion of the top of the pit by surface water. Lining the pit to the depth of unstable ground overcomes the problem.

Morgan[7], Bhaskaran[4]: Pit latrines may be used in areas subject to flooding provided the pit is extended upwards to above high water level and sealed from the ingress of surface water.

MacDonald[6]: The water table should be more than 3 ft (0.9 m) below ground level but it is preferable if there is 2 - 3 ft (0.6 - 0.9 m) of water in the bottom of the pit.

Iwugo et al.[16]: Constructing pits in rocky areas is difficult and expensive.

Boparai and Varma[2]: The P.R.A.I. type latrine should not be constructed in impermeable soils, at high altitudes, or areas likely to experience freezing temperatures, or in areas likely to be flooded.

1.3.2 Discussion

Pit latrines may be excavated in any type of ground although the conditions will affect the pit design. Pits in unstable soil require supporting; those in rocky ground will be difficult and expensive to excavate; and those in porous or fissured ground may pollute groundwater. When the ground is impermeable the pit may not be able to accept sullage.

Pit latrines work satisfactorily in areas subject to flooding and/or high groundwater level provided the pit contents are isolated from surface water and the floor slab is above maximum water level.

Pits may be constructed in fissured rocks only if it is certain that any water they contain will not be used for drinking since pollution flow in the fissures cannot be predicted (see Appendix 1).

Areas subject to a permanently high groundwater level may not be suitable for pit latrines because of construction difficulties.

Offset pit latrines such as the P.R.A.I. and R.O.E.C. are not recommended for areas liable to flooding as it is not normally possible to prevent contamination of surface water by pit contents.

1.4 Population Density

1.4.1 References

Langshaw[5]: Large numbers of pit latrines were constructed in the capital towns of the Windward and Leeward Islands without undue problems.

Sanches and Wagner[9]: Pit latrines were constructed in rural towns in Brazil.

Iwugo et al.[16]: Pit latrines are in use in the centre of a town where the population density exceeds 400 persons per hectare. Sufficient room is usually available for two pits which can then be used and desludged alternately.

World Bank[20]: It is not easy to define the population density at which pit latrines become unfeasible but the figure is most commonly around 250-300 persons per hectare for single storey houses and up to double that for two storey houses. However pit latrines have been found satisfactory in much higher population densities.

The essential points are whether there is sufficient space on the plot for two pits or whether the pit could be easily emptied if there is only space for one.

1.4.2 Discussion

The population density at which pit latrines become unfeasible will depend on the amount of free space available around the houses. If there is sufficient space for two pits (approx. 3 - 6 sq.m) there is no reason why pit latrines should not be considered.

Under certain circumstances it may be possible to use pit latrines where space is only available for one pit. The author was recently involved in designing a sanitation system for an urban area in Pakistan which had a population density in places exceeding 600 persons per hectare. Pit latrines were concluded to be the most appropriate system even though there was only enough space for one pit. This was because it was anticipated that by the time the present site was full (about 20 years) the water supply to the area would have increased to such an extent that a conventional piped disposal system will be required.

1.5 Water Requirements

1.5.1 References

Wagner and Lanoix[1], Morgan[7], MacDonald[6], Lamprell and Ramsay[2]: Pit latrines excavated to below groundwater level have been shown to have better digestion and to last longer.

1.5.2 Discussion

The addition of water to a pit latrine is not necessary for its proper functioning but for pits in dry areas where the ground is impermeable the judicial application of water (or sullage) to keep the pit wet will aid digestion and thus prolong its life.

1.6 Acceptable Wastes

1.6.1 References

Blackmore et al.[3], Iwugo et al.[17], Wagner and Lanoix[1]: Pit latrines can and do receive refuse and sullage if no other provision for their disposal is provided.

Bhaskaran[4], MacDonald[6], Boparai and Varma[2]: Water traps should not be fitted to pit latrines where water is not the normal material used for anal cleansing.

1.6.2 Discussion

The standard pit latrine will accept all types of faeces and anal cleansing materials and, if large enough and in porous ground, refuse and sullage. It is better if non-degradable refuse is not deposited since it will cause the pit to fill up more rapidly and may create difficulties if the pit is eventually to be emptied.

Latrines incorporating a water seal may only be used where water is the normal anal cleansing material. A separate opening in the pit will also be required if it is to accept refuse.

Offset latrines such as the R.O.E.C. would be inappropriate in areas where faeces tend to be fluid, especially if water is not used for anal cleansing. The faeces may stick to the chute producing unsightly conditions and attracting flies.

1.7 Pathogen Removal

1.7.1 References

Cram[11]: Ascaris eggs were little affected by sludge digestion at 20°C and 30°C after 3 months, and 10% were still viable after 6 months. Hookworm ova still hatched after 64 days digestion at 20°C and 41 days at 30°C.

Bagdasaryan[12]: Entero viruses survived in soil for 150–170 days, being more prolonged at low temperature (3–10°C) and pH 7.5 than at higher temperatures and more acid conditions. Survival was also longer in moist or sandy soil than dry or loamy soil.

Kligler[10]: Experiments in artificial pit latrines found that typhoid bacilli lived 10 days, dysentry 4 days and paratyphoid 10 days but not 15 days. In faeces typhoid lived up to 10 days and dysentry 8 days. Survival was longer in hard stools than soft ones.

Wagner and Lanoix[1]: Hookworm larvae have been observed to climb up the walls of pits and pass through a defective floor, where they could attach themselves to someone's bare foot.

1.7.2 Discussion

Most of the references available do not apply to the contents of pit latrines. Until further information is available it is suggested that pit contents should not be disturbed for a minimum of 6 months and preferably 12 months.

1.8 Recoverable Materials

1.8.1 References

Wagner and Lanoix[1], Kharkar et al.[14], Boparai and Varma[2]: The digested contents of a pit contain valuable soil nutrients and may be used as a soil conditioner.

1.9 Maintenance

1.9.1 References

Wagner and Lanoix[1], Morgan[7], MacDonald[6]: While the pit is in use no maintenance is required beyond the normal cleaning operations required for any sanitary fitting, provided it has been well designed and constructed. When the contents of the pit reach 0.5 m from ground level the latrine should be closed and the pit filled to ground level with soil.

Boparai and Varma[2]: The P.R.A.I. latrine pan should be cleaned and flushed with water periodically.

1.9.2 Discussion

Pit latrines are virtually maintenance free beyond the normal cleaning operations required of any toilet. Fly traps on vent pipes should be cleaned occasionally and it may be necessary to add some oil to a 'wet pit' from time to time to control mosquito breeding. It is also envisaged that emptying pits for reuse could also be a problem especially when the pit is deep and the contents semi liquid !

1.10 Location

1.10.1 References

Wagner and Lanoix[1], MacDonald[6]: The pit should be a minimum of 6 m from the house.

Boparai and Varma[2]: The P.R.A.I. latrine can be situated near or inside the residence.

1.10.2 Discussion

A well designed properly ventilated pit latrine will not smell or harbour flies and should therefore be located as close to the dwelling as possible. Care should be taken to ensure that the pit does not affect the house foundations or be affected by roof drainage. Two pits will ultimately be required and both should be equally accessible from the dwelling.

It is possible that the pit will pollute local underground water and care must be taken to ensure that this does not affect any nearby drinking water sources. Further details on this topic are given in Appendix 1.

Pits of the P.R.A.I. type could be located with the toilet inside the house.

1.11 Working Life

1.11.1 References

Wagner and Lanoix[1]: It is desirable for the working life to be 10-15 years but never less than 4 years.

Bhaskaran[4], Blackmore et al.[3]: Pit latrines should be designed to last 5 years.

1.11.2 Discussion

The time taken to fill a pit will depend on many factors but these can be allowed for in the design. The pit should be designed to last as long as possible (10-15 years if possible) as, in the long term, this will reduce costs, save space, encourage the construction of permanent and more hygienic structures and encourage people to continue using the latrine.

1.12 Problems

1.12.1 References

Iwugo et al.[16,17]: A survey of well constructed pit latrines serving over 50,000 people in Nigeria and Zambia found that most were operating satisfactorily. Those used by large families, however, did suffer some problems especially from odour and flies.

Pit latrines in another town, also well constructed, commonly suffered problems from flies and odour.

None of the pits were fitted with ventilation pipes but hole covers were provided.

Morgan[7]: Experiments carried out on four pit latrines in daily use found that in a period of 78 days 13953 flies were collected from the two pits that were unventilated and 146 from the two that were vented.

A further experiment found that when a large number of flies were released inside a vented pit latrine less than 5% tried to escape through the squatting hole.

Mosquito breeding was only found to be a problem in a wet pit latrine during the first year of its life. After this time the liquid surface was covered by a thick scum mat which prevented breeding.

Lawrence[13]: Culex Fatigans mosquitoes are attracted by volatile compounds and possibly methane and thus breed heavily in polluted waters but the larval survival rate decreases as the solid content of the liquid increases.

Blackmore et al.[3]: Poorly designed pit latrines in Botswana often had fouled pedestals or the pit walls caved in. Well designed and constructed pits in the same area suffered none of these problems.

1.12.2 Discussion

From the author's own experience many pit latrines are poorly designed and constructed. As a result they are often dirty, smelly and full of flies, if they have not yet collapsed.

A properly designed and constructed pit latrine however has none of these problems and for many situations can still be regarded as the best form of domestic sanitation.

Mosquito breeding may be a problem in a pit entering the groundwater, but as the solids content of the liquid increases and a scum layer starts to form on the surface the mosquitoes will disappear. During the early stages the mosquito breeding can be controlled by the addition of oil.

Pit latrines may also pollute nearby groundwater but further information on this topic is given in Appendix 1.

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2.0 THE BORED HOLE LATRINE

2.1 Introduction

The bored hole latrine is a quick way of producing basic sanitary facilities for single families. It is cheap and easy to construct in ordinary soils but because of the special equipment it requires, is more suitable when a large latrine programme is anticipated.

It consists of a hole, usually 0.2 m - 0.5 m diameter and 4 - 8 m deep covered with a floor slab similar to that used in a pit latrine and protected by an earth mound. The superstructure is also the same as that used in a pit latrine (see Fig. 4).

Whenever possible the hole is dug to penetrate the groundwater as this prolongs its life and the top is lined to prevent caving in.

The hole may last from 1 - 10 years depending on circumstances. When it is nearly full a new hole is dug, the floor slab moved and the old hole filled with soil to ground level.

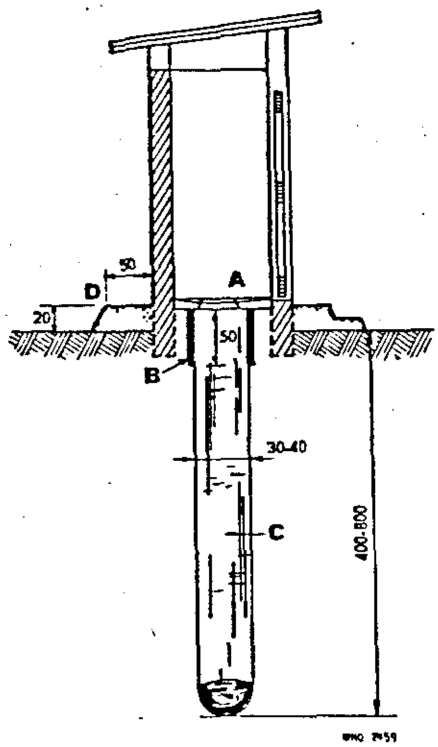
2.2 References for Design and Construction

Wagner and Lanoix[1], Yeager[4], Lamprell and Ramsay[3].

2.3 Terrain and Ground Conditions

2.3.1 References

Wagner and Lanoix[1], Watson[2], Lamprell and Ramsay[3]: Bored hole latrines frequently collapse in sandy or alluvial soil or during the rainy season. This can be avoided however by lining the hole. The life of the hole is considerably improved if it penetrates groundwater. In flood plains or tidal areas the floor should be elevated above the highest water level and the mound made watertight.



Measurements shown are in centimetres.

A = Squatting slab. Note sides sloping towards hole
B = Impervious clay-tile lining
C = Woven-bamboo lining
D = Earth mound, well tamped

Fig. 4. TYPICAL BORED HOLE LATRINE

Langshaw[5], Watson[2]: The hole cannot be excavated in boulder strewn subsoil.

Lamprell and Ramsay[3], Watson[2]: Digging the hole below the water table can sometimes be very difficult.

In areas where the water table rises to very near the surface or where the hole is in impervious strata and fills up with surface water care must be taken to ensure that the squatting plate is sufficiently elevated above the maximum water level to prevent splashing the user.

2.3.2 Discussion

Bored hole latrines are unsuitable for soils containing boulders or gravel beds and for hard rock as hand boring in such strata is difficult or impossible. Areas of fissured shales and clays may only be used if the groundwater is already polluted (see Appendix 1). Holes in unstable ground will be difficult to excavate and will require lining.

If possible the hole should penetrate the water table as this prolongs its life but boring holes in water laden soils is often difficult and so the operation is best carried out when the water table is at its lowest.

2.4 Population Density

2.4.1 References

Watson[5]: For small and isolated groups of people the bored hole latrine, one for each family or small group, provides a means of disposing of human excreta which has proved successful in several different countries.

2.4.2 Discussion

Bored hole latrines have a short life span and are very difficult to empty. It is therefore necessary to have sufficient space to dig a new hole each time one fills. This type of latrine is not suitable to urban areas where house plots are small unless it is only being considered as a temporary form of sanitation to be replaced in a short time by a more permanent system.

2.5 Water Requirements

2.5.1 References

Watson[5]: Flies find difficulty in breeding in water so if there is no permanent water in the latrine a few buckets of water thrown in daily may remove any nuisance.

2.5.2 Discussion

The addition of water is not necessary for the proper operation of the latrine. The suggestion made by Watson[5] may be correct but no other reference is available to corroborate it.

2.6 Acceptable Wastes

2.6.2 Discussion

As with pit latrines, bored hole latrines are likely to receive domestic refuse and sullage if no other facilities for their disposal are provided.

Sullage will not cause problems provided the soil is porous enough to accept the quantity deposited but refuse should not be put in as the hole is not big enough to accept it and will quickly fill up.

The use of anal cleansing devices such as stones, corn cobs, twigs, etc. will also reduce the hole's effective life.

2.7 Pathogen Removal

See Pit Latrines, section 1.7.

2.8 Recoverable Materials

2.8.2 Discussion

It is usually impossible to remove the contents from a bored hole latrine because of its narrowness and great depth.

2.9 Maintenance

See Pit Latrines, section 1.9.

2.10 Location

2.10.1 References

Watson[5]: The latrine can be put conveniently near the user's home, usually only some 10-20 ft away.

2.10.2 Discussion

Because of the fly and odour nuisance bored hole latrines should be placed down wind from the house and as far from the kitchen as possible without deterring people from using it. If a water seal toilet is fitted, however, the nuisances will be eliminated and the latrine could be located closer to the house.

Care must be taken to see that polluted groundwater will not reach a water source (see Appendix 1).

2.11 Working Life

2.11.1 References

Wagner and Lanoix[1]: A latrine dug in dry ground and used by a family of 5 or 6 will not last more than 1½ - 2 years. Its life is considerably improved however if it can penetrate groundwater for at least ⅓ of its depth.

Largshaw[6]: Found that a latrine lasted up to 5½ years if not overloaded.

Lamprell and Ramsay[3]: Latrines lasted 5 people 2 - 3 years if the hole was above the water table, and up to 8 years if in the water table for a considerable distance.

2.11.2 Discussion

The life of a bored hole latrine will depend on its size, depth, groundwater level and velocity, soil type, the wastes deposited and the number of users. All these factors will vary from place to place but normally a hole 0.4 m dia and 4 - 8 m deep not entering the groundwater may be expected to last 1 - 3 years, and a hole penetrating the groundwater for much of its depth 5 - 8 years.

2.12 Problems

2.12.1 References

Lamprell and Ramsay[3], Watson[2]: Flies and mosquitoes only become a real problem when the water table or pit contents are near the surface. Their numbers can be controlled by covering the surface with a layer of thick oil.

Dyer and Bhaskaran[7]: A borehole fed with night soil daily was infested with large numbers of flies. However it is probable that the night soil contained large numbers of larvae before it was deposited in the hole.

Wagner and Lanoix[1]: The greatest problem is the frequent collapse of the hole in sandy or alluvial soil or during the rainy season. This can be avoided by lining the hole.

Often a scum forms over the water in the hole and further solids float on top of it ; this effectively reduces the size of the hole and removes the degradation powers of the liquid.

2.12.2 Discussion

Unlike pit latrines it is not possible to prevent problems from flies and odour by providing ventilation within the hole. The problems could be prevented if the slab was fitted with a waterseal, but in places where this is not acceptable frequent additions of oil and/or water may be the only answer other than keeping the hole tightly covered when not in use.

2.13 Details of References

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3.0 COMPOSTING LATRINES

3.1 Introduction

A reasonably safe way for a family to prepare its excreta and refuse for use as a fertilizer is to compost it in a privy. There are two types of composting privy; those that work under anaerobic conditions and those that work under aerobic conditions.

Anaerobic composting Night soil, refuse and animal wastes are collected in a large pit or vault. When the pit is full (usually 6 - 12 months) it is completely sealed and the contents allowed to digest. Whilst this is happening a similar pit is in use and when this is full the first pit is re-opened and its contents removed to be used as a fertilizer. In this way the pits are used alternately and a batch of fertilizer is produced every time one of the pits is re-opened.

There are numerous minor variations in design of the latrine but basically they can be divided into those that use an unlined pit and are similar to a standard pit latrine (Fig. 1) and those that use a watertight vault (Fig. 5). Some of the units with watertight vaults have a separate collection system for urine so that it can be applied directly to the soil before any of its nitrogen value is lost.

Aerobic Composting (Multrum) (Fig. 6). Night soil and refuse mix in a large vault. Air circulating through the result allows aerobic bacteria to degrade the mixture until it becomes harmless and odourless compost. The vault is built on a slope so that the mixture slowly slips along the floor and by the time it reaches the lowest level of the vault it is fully digested. The mixture can then be safely removed and used as a soil conditioner. The system is continuous so that once it has been started it will work indefinitely provided it is correctly operated.

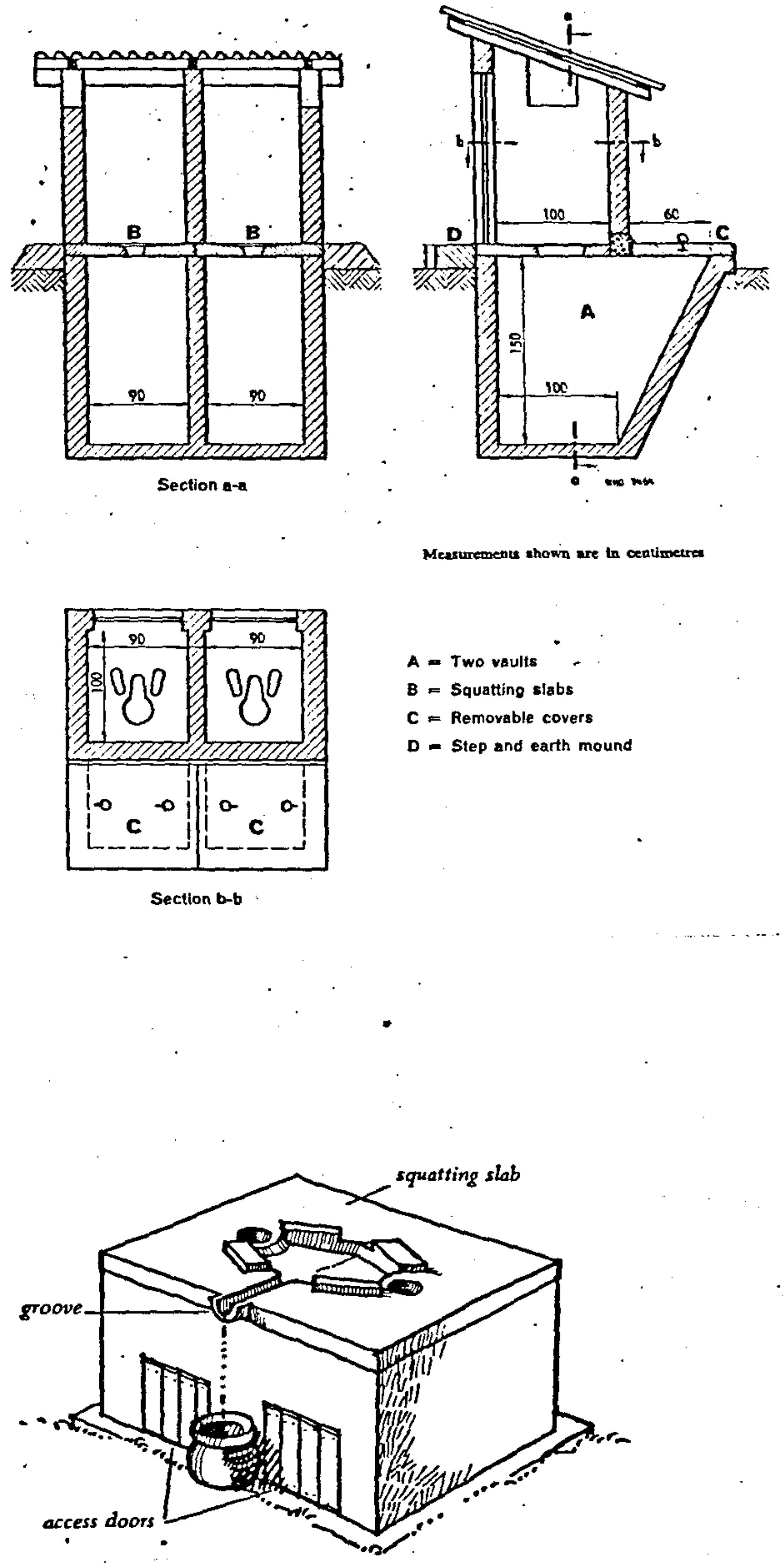

Fig. 5. TWO DESIGNS OF DOUBLE VAULT LATRINE.

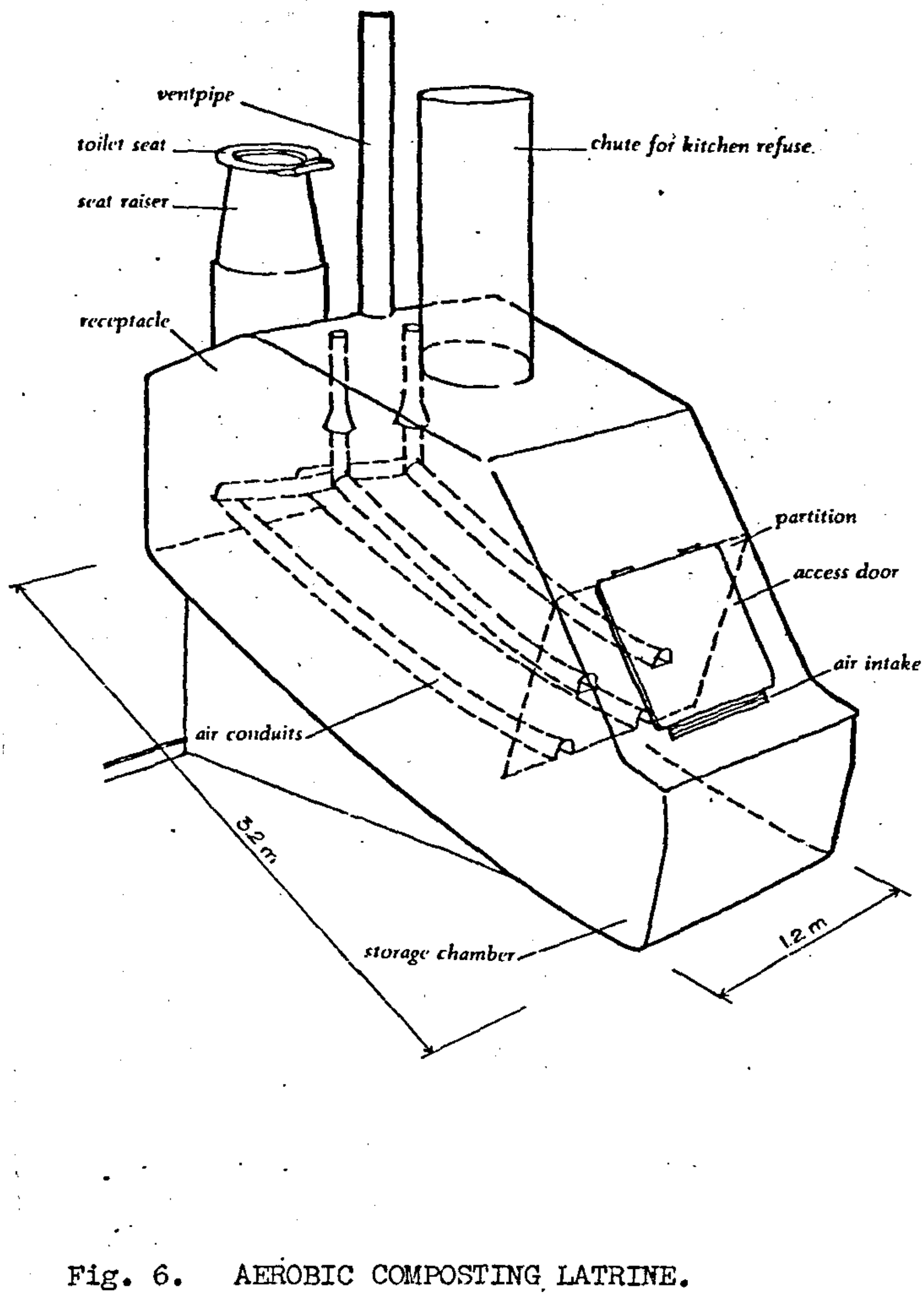

Fig. 6. AEROBIC COMPOSTING LATRINE.

3.2 References for Design and Construction of Composting Toilets

Anaerobic: Winblad[5], Wagner and Lanoix[10], McMichael[11].

Aerobic: Lindstrom[6], Winblad[5], Rybczynski[7].

3.3 Terrain and Ground Conditions

3.3.1 References

McMichael[11]: The double vault latrine can be constructed anywhere that is not subject to flooding. Since it may be constructed above the ground and does not cause any ground pollution, its siting is virtually independent of ground conditions.

Wagner and Lanoix[10], Winblad[5]: When the composting chamber is an unlined hole in the ground the governing ground conditions will be the same as for a pit latrine, except that it must be above the ground's water table.

If the vault is fully lined it is independent of the ground conditions but it should be constructed above groundwater level.

Ehlers and Steel[12]: The concrete vault privy does not contaminate groundwater, surface water or soil.

Gotaas[13]: Anaerobic composting can take place in stacks containing a moisture content of 40 - 75% into which oxygen can penetrate, or in 80 - 90% moisture content where the organic material is suspended in liquid.

Lindstrom[6]: The multrum tank should be placed mostly below ground in a firm well drained subsoil. The unit is equipped with thick sides and bottom which completely prevent contamination of the surrounding soil.

3.3.2 Discussion

The terrain and ground conditions in which unlined composting privies can be built are the same as for a pit latrine (see section 1.3). Anaerobic composting can take place in the dry or the liquid state so that in theory it does not matter whether the ground water enters the pit. In the case of the householder who has to maintain his own privy, however, it is probably better to keep the pit contents fairly dry to reduce emptying difficulties. In areas where privies are to be emptied by the municipality wet pit contents may be an advantage as they can be emptied mechanically, thereby reducing mess, manpower and time.

Fully lined, watertight composting privies are not affected by ground conditions or the level of the ground water table as they can be constructed above or below ground. Care should be taken, however, to guard against flotation if the privy is built in ground with a high water table.

Aerobic composters fitted with a drain cannot be installed below the highest groundwater level as the groundwater will flood the vault and stop the decomposition process.

Most bacterial action will cease if the temperature of the bio mass drops below 10°C. Composting privies cannot be recommended therefore for areas where such temperatures are likely to exist for a significant part of the year.

3.4 Population Density

3.4.1 References

McMichael[11]: Compost double vault latrines have been constructed in villages in Vietnam. The latrines must be 10 m from the house.

Wagner and Lanoix[10]: Composting privies are suitable for villages.

Ehlers and Steel[12]: Suitable for the average family.

Winblad[5]: The maximum number of users of an aerobic composter depends on factors such as temperature, humidity, quantity of refuse, proportion of urine and faeces and volume of receptacle. In most cases 8 – 10 people would be the maximum for one latrine.

Lindstrom[6]: In Europe the aerobic composting latrine is suitable for areas where no sewage treatment plant exists or where sewers are leaky, or where refuse and excreta disposal pose practical economic problems.

3.4.2 Discussion

The proper operation of a compost latrine requires a daily input of organic matter which is at least five times the volume of the excreta deposited. It is unlikely that this quantity of material (0.01 m^3/capt/day) would be available in high density urban areas or very poor areas where refuse can be more profitably used as animal fodder or fuel.

The system would, however, be applicable to rural areas and suburban areas where houses normally have a garden.

3.5 Water Requirements

3.5.1 No references are available on this topic.

3.5.2 Discussion

The moisture content of the bio mass is an important factor in effective composting. Normally sufficient moisture is added in the form of urine or green vegetable matter in the refuse, but it is possible that pit privy composters in very permeable ground and aerobic composters in very hot arid climates may require the occasional addition of small quantities of liquid.

3.6 Acceptable Wastes

3.6.1 References

Winblad[5], Lindstrom[6], Rybczynski[7]: The multrum can accept faeces, urine, organic kitchen and household residues, vegetable and meat scraps, peelings, bones, eggshells, floor sweepings, sanitary napkins and grass clippings.

Metal, glass, plastic, large amounts of liquid or material which could get hung on the air conduits and impede settling of the pit should not be put in.

Hills[8]: Bath and washing water must be dealt with separately.

Wagner and Lanoix[10]: Anaerobic composters will accept similar materials to the multrum and additionally animal manure. The ratio of night soil to refuse should be regulated at around 1:5 by volume.

McMichael[11]: The Vietnamese double vault privy has provisions for the separate collection of urine. Kitchen ashes should be sprinkled on the pile after each use to deodorize it and inhibit flies.

3.6.2 Discussion

The articles that can be put in a composting latrine are adequately described by the preceding references.

Sullage should not be put in a lined composter, but it could be put in an unlined privy provided the ground was permeable enough to leach it away.

3.7 Pathogen Destruction

3.7.1 References

Gotaas[13], Winblad[5], Wagner and Lanoix[10]: Anaerobic decomposition of organic matter does not release sufficient heat energy to significantly raise the temperature of the organic mass and therefore cannot be used for destruction of pathogens. The pathogenic organisms do disappear in the organic mass owing to being in an unfavourable environment and to biological antagonism. The disappearance is slow and materials must be held for six to twelve months to ensure the relatively complete destruction of Ascaris eggs.

Nichols[3]: Bacterial analysis of the final material of seven multrums in Sweden and two in the United States found the numbers and types of bacteria in the sample to be similar to those found in soils. No E.Coli were found in the sample and the pathogenic bacteria found were of a species known to occur widely in soils.

Winblad[5]: It is possible for pathogenic organisms in a multrum to be washed from the top of the site to the storage chamber thus causing a health risk.

Gear[9]: A multrum recently installed in the U.K. suffered a build up of liquid in the final chamber. This was probably due to insufficient bedding material in the vault and the input of a large quantity of wet leaves. A large number of flies were also observed breeding in the final chamber, but not in the other compartments.

3.7.2 Discussion

Pathogen removal in anaerobic composters is adequately described by Gotaas and Winblad. Some privies have provisions for the separate collection of urine and, in such cases, care should be taken to see that it is disposed of safely as it may contain pathogens. Pathogen destruction in anaerobic composters is greatly dependent on proper operation and maintenance. If the number of people using the vault or the quantity of refuse deposited is consistently greater than that for which it was designed, then the vaults will fill up too quickly and this may lead to some viable pathogens still remaining in the compost when it is removed from the vault.

In aerobic composters material does not usually enter the final chamber until at least a year after its deposition so there is little risk of any pathogens still being viable. Any liquid in the end chamber, however, is likely to be of more recent origin and may still contain pathogens. If flies breed in this area there is a possibility of disease transmission.

3.8 Recoverable Materials

3.8.1 References

Fogel[1]: Chemical tests on seven 'Clivus multrums' produced the following results.

Average organic matter 58%, which is comparable with garden compost that usually falls in the range 30–60%.

The C/N ratios was 13 which indicates that the material is stable.

Approximately 3 kg of multrum compost will have the same fertilizer value as 1 kg of 10:10:10 fertilizer, which is considerably superior to garden compost or municipal compost.

Multrum compost also contains numerous trace elements needed by plants in small amounts that will not be dangerous at normal levels of compost spreading.

Nichols[3]: Numbers and types of bacteria found in a Clivus multrum were similar to those found in an ordinary garden compost, indicating that the material is suitable for a soil amendment.

Winblad[5], Wagner and Lanoix[10]: The quality of the fertilizer produced from anaerobic digestion will depend on the proportion and quality of night soil and refuse deposited. Some of the nitrogenous matter will have been lost because of seepage of some of the liquids, especially urine. Its value is mainly as a soil conditioner, improving the organic content, making the soil easier to cultivate and improving the water holding capacity.

3.8.2 Discussion

Adequate explanation is provided by the sources of information.

3.9 Maintenance

3.9.1 References

(a) Anaerobic composting latrines

McMichael[11]: Before use the vault floor should be covered with a layer of powdered earth. The excreta should be covered with a layer of kitchen ashes after each visit; the hole should be kept covered. When the vault is 2/3 full its contents should be levelled with a stick and the tank filled with dried powdered earth.

Wagner and Lanoix[10]: The bottom of the vault should be covered with 50 cm of grass cuttings, fine leaves, garbage, paper, etc.

Each day refuse, animal manure, and urine soaked earth and straw should be put in so that the ratio of night soil to other material is about 1:5 by volume.

About once a week a few kilos of grass clippings and fine textured leaves should be thrown in.

When the pit contents reach 50 cm from the top the contents should be levelled and covered with 15 cm of grass clippings and leaves and 35 cm of well tamped earth.

Winblad[5]: As Wagner and Lanoix, plus:

Sprinkle ashes, husks or powdered earth on excreta after each use and replace lid to deodorize the excreta, absorb moisture and make the faecal matter less attractive to flies.

When the composted material is removed leave some behind to act as bedding for the new material.

Ehlers and Steel[12]: The cleaning door and seat must be well maintained, kept closed and fly tight.

(b) Aerobic composting latrines

Winblad[5], Rybczynski[7]: Before use the floor of the vault has to be covered with a thick layer of leaves, rich soil and grass cuttings. Each day add kitchen leftovers and floor and yard sweepings. Several times a week add grass cuttings, weeds and straw or leaves. After each defaecation add ashes to deodorize the excreta and to make it less attractive to flies. About once or twice a year empty composted material out of the final chamber.

3.9.2 Discussion

(a) Anaerobic composting

Adequate explanation is given by Wagner and Lanoix and Winblad, but in addition a careful watch must be kept on the moisture content of the material especially in a watertight vault. If contents are too wet, add ashes or husks, and if too dry add green vegetation or water

(b) Aerobic composting

Adequate information is given by the quoted references.

3.10 Location

3.10.1 References

McMichael[11]: The tank should be a minimum of 10 m from dwellings and water tanks.

Winblad[3], Wagner and Lanoix[10]: The location of non watertight privies with respect to a water supply is the same as for a pit latrine.

The distance from a dwelling is determined by the housing density and considerations of convenience and nuisance. Odours need not be a problem if the latrine is well ventilated, but insects may be. The distance between latrine and kitchen should be as far as possible to prevent cross infection from flies, but it should not be so far as to militate against its use.

Multrums may be installed inside a dwelling but there may be problems with fruit flies, and on still humid days some odours. These problems are not noticeable when the latrine is placed in a separate shelter some distance from the house.

3.10.2 Discussion

There is no reason why a properly designed, constructed and maintained anaerobic privy should not be located close to the dwelling. Flies should not cause problems if the vault is properly ventilated and the vent pipe fitted with a fly screen.

In temperate regions mouldering toilets can be located close to, or even inside, a dwelling as the vent pipe will produce sufficient ventilation to prevent the ingress of odours into the house. In tropical regions however there is a possibility that the unit could smell or attract flies.

3.11 Working Life

3.11.1 References

McMichael[11]: Each compartment should provide a retention time of 2 months.

Wagner and Lanoix[10]: The working life of each compartment depends on its size, but it should be as big as possible and have a minimum life of 6 months.

Ehlers and Steel[12]: A capacity of 10-15 ft^3 will last the average family three to six months.

Winblad[5]: The aerobic composter is never emptied. The floor has a 30° slope and the final material slowly slides into the end compartment from where it can occasionally be removed.

3.11.2 Discussion

The working life of the anaerobic privy between emptyings will depend on the capacity of the privy and the volume of matter deposited, but each compartment should have a minimum retention time of six to twelve months to ensure the death of most pathogens.

Most mouldering toilets are continuous and should work indefinitely provided they are correctly maintained.

3.12 Problems

3.12.1 References

Blackmore and Boydell[2]: Continuous aerobic composting units that have been in operation for 3 months have suffered considerable nuisance from flies and odour. Compared with other forms of unsewered sanitation they are more sensitive to the degree of user care, non-closure of the seat cover and the number of users.

Eygelaar[4]: Continuous aerobic composting latrines in operation in Tanzania for just under a year tended to suffer from some flooding, probably due to too many users, the use of water after defaecation and the use of the toilet as a bathroom. The liquid was allowed to drain into the ground.

No odours were apparent when seat covers were left off. Flies did breed in the tank but most were in the chamber further from the toilet seat and no flies were in evidence in the toilet cubicle. Any increase in smell indicated unsatisfactory working and could be remedied by adding grass.

Winblad[5]: Latrines constructed inside the dwelling may have problems with fruit flies and, on still humid days there may be some odours.

Rybczynski[7]: Most composting and mouldering toilets seem to have a common problem with flies at the beginning of their operation.

Gear[9]: A multrum toilet recently installed in the U.K. has had no problems from odour but there has been a large build-up of flies in the final compartment. There has also been a build-up of fluid in the final compartment due to poor operational control.

Wagner and Lanoix[10]: The double vault system is rather complicated and may, in the beginning, be beyond the comprehension of most rural families. Both compartments are often used simultaneously thus defeating their purpose.

Ehlers and Steel[12], Hardenbergh[14]: Experience has shown that double vaults do not come up to expectation. As a rule the clearing door and the seats are not well maintained with the consequence that flies enter in great numbers. The vault is frequently neglected and allowed to overflow and clearing them under crowded conditions is a dangerous procedure.

3.12.2 Discussion

Most aerobic composting toilets seem to suffer from odours and flies especially in the early stages of operation. If the latrine is properly maintained these problems can be easily overcome, but poor maintenance and prolonged overuse will quickly cause the system to break down.

In areas where relatively large quantities of liquid are deposited there may be some problems with flooding of the final compartment, and the possibility of infection from pathogens washed out of the composting material by the liquid.

It is possible that at times of high air temperature or still conditions the natural ventilation system of the latrine could reverse, producing strong odours in the privy building.

Both systems are complicated and it may take considerable effort to train people in their operation.

Improper use of anaerobic composters will lead to odours, flies, difficult to handle compost and material in both pits.

3.13 Details of References

1. Fogel, M., Feb. 1977. Chemical analysis of Clivus multrum compost.

2. Blackmore, M.D., Boydell, R.A., Mbere, N., Moselele, P., 1977. Low cost sanitation research report No.3. Min. of Local Government and Lands, Botswana, and International Development Research Centre.

3. Nichols, H.W., 1976. Analysis of bacterial populations in the final product of the Clivus multrum. Centre for the Biology of Natural Systems. Washington University, St. Louis, Miss.

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5. Winblad, U., Kilama, W., Toretinason, K., 1978. Sanitation without water. Preliminary edition. Pub. Sundt. Offset, Stockholm. ISBN 91-7260-187-6.

6. Lindstrom, R., 1965. A simple process for composting small quantities of community wastes. Compost Science U.S.A., Spring 65, pp. 30-32.

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8. Hills, L.D., 1972. The Clivus toilet - sanitation without pollution. Compost Science U.S.A., May-June 72, pp. 8-11.

9. Gear, A., 1978. Personal communication. Engineer. Henry Doubleday Research Association, U.K.

10. Wagner, E.G., Lanoix, J.N., 1958. Excreta disposal for rural areas and small communities. W.H.O., Geneva, Monograph No.39.

11. McMichael, J.K., 1976. Health in the Third World, Studies from Vietnam. Pub. The Bertrand Russell Peace Foundation for Spokesman Books, U.K.

12. Ehlers, V.M., Steel, E.W., 1960. Municipal and Rural Sanitation. 4th Ed. Pub. McGraw-Hill Book Co. Inc. U.S.A.

13. Gotaas, H.B., 1956. Composting, sanitary disposal and reclamation of organic wastes. W.H.O., Monograph No.31, Geneva.

14. Hardenbergh, W.A., 1924. Home sewage disposal. Pub. J.B. Lippincott Co., U.S.A.

4.0 AQUA PRIVIES

4.1 Introduction

The aqua privy (Fig. 7) is a water filled tank located directly underneath the point of defaecation. The tank allows the solids to settle and form a sludge that digests anaerobically and the liquid effluent flows out through the outlet pipe. Water, not necessarily clean, is regularly added to the tank to maintain the liquid level and assist digestion. Odours are prevented from entering the latrine by a long drop pipe extending from the toilet to below the liquid surface or by a water seal toilet. The effluent is disposed of by one of various methods depending on the prevailing conditions. The sludge that accumulates in the tank is periodically removed.

Frequently the latrine is annexed to a shower or wash basin and the sullage from them used to keep the privy tank topped up.

4.2 References for Design and Construction

Vincent et al.[1], MacDonald[6], Blackmore et al.[10], Sebastian and Buchanan[2], Feachem and Cairncross[17], Wagner and Lanoix[18].

4.3 Terrain and Ground Conditions

4.3.1 References

Vincent et al.[1]: Numerous aqua privy schemes have been constructed in Zambia under tropical and sub-tropical conditions over areas of flat topography in soils of low permeability. The tank effluent is disposed of to waste stabilisation ponds.

Sebastian and Buchanan[2]: Aqua privies in Anguilla were constructed in low lying land covered in scrub and salt ponds with limestone very

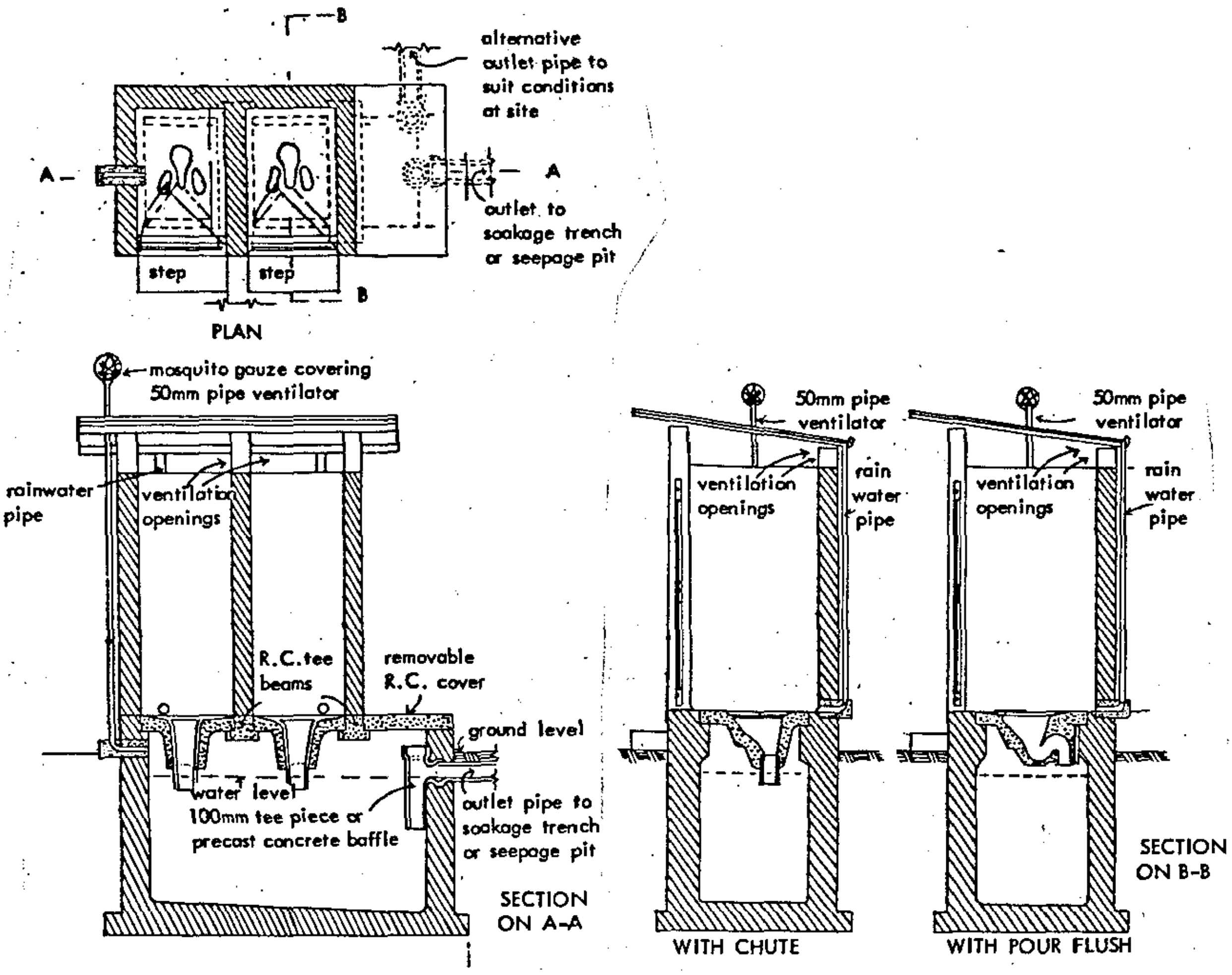

Fig. 7. AN AQUA PRIVY FOR TWO FAMILIES

near the surface. The effluent is disposed of in shallow trenches by absorption and evaporation.

Majumdar et al.[3]: Aqua privies are functioning in West Bengal, India, where the topography is flat and the groundwater high. The effluent is disposed of in soakaways.

Oluwande[4]: When the water table is high the privy tank can be built above ground to ease construction.

4.3.2 Discussion

Since the aqua privy is a watertight tank its construction will not be prevented by varying ground conditions, although they will affect the cost of construction. The choice of effluent disposal system however will be largely controlled by the ground conditions.

Seepage pits are unsuitable for impermeable ground, areas subject to flooding or with a high ground water table (above tank effluent pipe invert), rocky ground or fissured ground if it contains potable groundwater.

Percolation trenches have similar constraints to seepage pits but will operate in less permeable soils and areas with a thin soil covering over rock (minimum 1 metre).

Evapotranspiration beds are unsuitable in areas of high rainfall as they may pollute surface waters or at low temperatures as it will prevent plant growth and retard evaporation.

A piped effluent system to stabilisation ponds or conventional sewage works may be difficult and expensive to construct on level land, high water table, or rocky ground.

Continuous low temperatures may cause the privy tank contents to freeze which would render it unusable and could cause structural damage.

4.4 Population Density

4.4.1 References

Vincent et al.[1], Blackmore et al.[10]: Aqua privies have been constructed in low cost, high density housing areas.

Sebastian and Buchanan[2], Majumdar[3], Hepburn[12]: Privies have been built in small communities and scattered rural homes having a poor water supply.

4.4.2 Discussion

Aqua privies can be used in rural and urban areas. In rural areas the sewered system is not recommended because of the cost and maintenance required.

In urban areas the type of system that would be most suitable will depend partly on available space, In suburban areas seepage systems could work provided the plots are big enough, whereas sewered systems are more suited to urban and high density urban areas.

4.5 Water Requirements

4.5.1 References

Vincent et al.[1], Blackmore et al.[10], Ross Inst.[8]: The water necessary for the proper functioning of the system will be provided if household sink and shower waste water is directed into the tank.

Majumdar et al.[3]: Aqua privies in Bengal were found to be working effectively when receiving 5.4 - 6 l/caput/day including faeces and urine.

Langshaw[5]: Add 1 bucket of water per day.

Sebastian and Buchanan[2]: Add 1 to 5 buckets of water per day.

Vincent et al.[1]: Aqua privies can be kept topped up with water by connecting a number in series and topping up the first privy from a communal wash house or the effluent from a public standpipe.

Indian Engineering[9]: Add 1 or 2 buckets of water per week in addition to ablution water.

Hepburn[12]: A communal A privy in Australia is served only by the rainwater that falls on the roof of the latrine and works quite satisfactorily.

Drew[13]: Sea water has been used for tank topping up without bad effect.

Iwugo et al.[15, 16]: The aqua privies in New Buasa, Nigeria and towns in Zambia apparently fill up and suffer from flies and smell only when insufficient water is available for flushing. The drain pipe from the shower appears to enter the tank above water level and does not have a water trap. The tanks are also quite small and, in the case of Zambia, have not been emptied for up to 18 years.

4.5.2 Discussion

Aqua privies require a regular supply of water to assist in liquifying and diluting the sludge and in compensating for losses due to evaporation and leakage; however the quality of the water appears to be of little consequence.

The quantity of water required appears to be quite small and the disposal of sink and bathroom wastes to the privy will adequately meet the requirements.

Connecting tanks in series is a possibility, provided conditions are suitable, but it has a number of drawbacks and constraints, namely:

(i) The privies must be accurately levelled and aligned.

(ii) Tanks may have to be deeper to provide sufficient. cover for the sewer.

(iii) All the tanks on the line must be constructed before the system can be operated.

(iv) A blockage in one of the tanks will affect all of the tanks upstream of it.

(v) Excess liquid in the system will mean that the tanks have to be larger to provide adequate retention and prevent turbulence.

(vi) Communal effluent disposal facilities must be available.

4.6 Acceptable Wastes

4.6.1 References

Vincent et al.[1], Langshaw[5], Iwugo et al.[15]: Aqua privies can accept excreta and all liquid wastes from kitchen and bathroom.

MacDonald[6], Oluwande[4]: Any anal cleansing materials can be deposited in aqua privy tanks provided they will go down the dip pipe. If non bio degradable materials are used, however, the tank will require desludging more often.

Iwugo et al.[16]: Many aqua privy users in Zambia have taken to incinerating their used anal cleansing material rather than put them in the privy because of the likelihood of blocking the sewer.

Feachem et al.[17]: Refuse should not be put in an aqua privy.

4.6.2 Discussion

The materials deposited in an aqua privy should be restricted to excreta, urine, anal cleansing materials and sullage. When the anal cleansing materials are non bio degradable the time between desludgings will be reduced.

The disposal of refuse in a privy, although possible, cannot be recommended as it would considerably reduce the time between desludging, and produce a sludge that would be difficult to remove.

4.7 Pathogen Removal

4.7.1 References

Vincent et al.[1]: The B.O.D. of the tank effluent is approximately 50% of that of the influent.

Majumdar et al.[3]: Aqua privies in Bengal were found to reduce the helminth count in the effluent by 85%.

Lumsden et al.[11]: The effluent from the privy tank is still dangerous and requires further treatment before disposal.

4.7.2 Discussion

The retention time for liquid in aqua privies is insufficient to destroy pathogenic organisms and it must therefore receive treatment before being discharged.

Pathogens in the sludge will die off with time but it must be remembered when desludging that the most recent sludge will still retain pathogenic organisms and should therefore receive further treatment.

Most final disposal methods if properly designed and constructed are not a health risk, but evaporation beds could be a source of mosquito breeding.

4.8 Recoverable Material

4.8.1 References

Wagner and Lanoix[18]: The scum and sludge removed from ordinary septic tanks will normally contain some undigested portion which is still offensive and potentially dangerous to health. Such sludge should not be used immediately as crop fertilizers, but may be composted along with other organic waste; otherwise it should be buried in shallow trenches.

4.8.2 Discussion

Sludge from the aqua privy tank may be used as a soil conditioner provided it is composted or stored for 6-12 months first to ensure the death of all pathogenic organisms.

If the effluent is discharged to stabilisation ponds some of them may be used for algae or fish production. Evapotranspiration beds could be used for crop production.

4.9 Maintenance and Problems

4.9.1 References

Majumdar et al.[3]: Emptying of the tank is a problem when no machinery is available. In Bengal buckets are used to empty the tanks which, because of spillage, exposes the emptying staff and local inhabitants to further infection.

Oluwande[4]: Aqua privies do not create a nuisance or smell provided the water seal around the drop pipe is retained and faeces are not left in the drop pipe. The drop pipe should be cleaned daily with water. Where newspaper is used for anal cleansing the pages should be in small pieces to prevent blockage of the drop pipe.

Langshaw[5]: Privies installed in the West Indies were trouble free. Some mosquito breeding occurred when the units were put into operation, but this stopped after development of septic action.

Sebastian and Buchanan[2]: Privies in Anguilla were trouble free and did not produce any smells.

Hepburn[12]: Communal A. privies in Australia work well even though there is no regular attendant to maintain them. Occasional problems from mosquitoes and flies could be stopped by the addition of kerosene to the tank.

Iwugo et al.[15]: In New Buasa, Nigeria, many of the residents take considerable pride in their privy. They are clean, tidy and generally free of nuisance from odour or flies provided sufficient water is available for flushing.

Desludging, which is the responsibility of the owner, is carried out manually and the heavy concrete floor slab has to be removed for the purpose. The sludge is generally buried in the courtyard in a ditch dug adjacent to the latrine block. This is objectionable and unsatisfactory because of the small lot size.

4.9.2 Discussion

Provided a well designed and constructed aqua privy receives sufficient water and the squatting plate and drop pipe are kept clean it will be trouble free between desludgings.

The removal and disposal of sludge from aqua privies should be given considerable thought when choosing a suitable disposal system. In communities where mechanical plant such as the gully emptiers can be afforded and are accessible, the desludging procedure should create little difficulty. When such plant is not available, however, careful consideration should be given to the suitability of the system. The emptying of privies with buckets or the disposal of sludge in areas where people are likely to walk is dangerous since some of the sludge may still contain pathogens. Emptying using hand pumps into sealed containers drawn by oxen or the like may be acceptable but, as with all the emptying methods it must be well organised and managed.

After the sludge removal is complete the tank should be refilled with water and a small amount of fresh sludge returned to the tank to start digestion.

Effluent disposal systems such as sewers to communal treatment works and evaporation and evapotranspiration beds will require a substantial amount of skilled maintenance to keep them operating properly.

4.10 Location

4.10.1 References

Vincent et al.[1], Iwugo et al[16]: Privies can be constructed at common house boundaries so that 2,3 or 4 houses can share a tank and some of the walls thus reducing construction costs.

MacDonald[6], Ross Inst.[8]: Locate the privy close to the house but provide it with a separate entrance.

Sebastian and Buchanan[2]: Several privies were constructed within a house with no complaints from the inhabitants.

Hepburn[12]: Aqua privies should not be constructed inside the dwelling because of the problem from smell (Note: this particular design does not have a water seal on the privy).

4.10.2 Discussion

An aqua privy can be located in any convenient position provided the latrine and tank are adequately ventilated and the access to the tank is situated so as to be easily reached by the sludge removal system being used.

Construction costs can be reduced by siting the latrines at plot boundaries and building a common tank. With this sytem however it is necessary to provide an emptying service not paid for by the householder as it is likely to lead to communal difficulties when trying to share the costs.

It would appear that aqua privies can be located within the house without difficulty but the desludging point should be outside.

4.11 Working Life

4.11.1 References

Vincent et al.[1]: The period between desludgings will depend on the volume of the tank but an allowance of 16-34 ft^3/person should give 16-20 years between desludging.

Pickford[7]: A visit to aqua privies in Zambia approximately 18 years after their installation found them completely full and the indication given by the local inhabitants was that they had been that way for many years. The sludge was well digested and gritty and the system was only kept working by the continuous flow of water through the tank. The premature filling of the tanks was probably caused by grit being carried into the latrine on the feet of the users and this being washed into the tank.

Similar privies in Botswana provided with pedestal seats showed little build-up of sludge and no sign of silt after 15 months of operation.

Sebastian and Buchanan[2]: Aqua privies in Anguilla serving 1-5 persons were found to require emptying approximately every 7 years. The sludge storage capacity was 0.6 m^3, and the tank received excreta and toilet paper only. A pedestal seat was provided.

Ross Institute[8]: Privies should be designed to have a working life of 11 to 20 years.

Indian Engineering[9]: A privy having a sludge storage capacity of 4.8 ft^3 will last 4 to 5 persons one year.

Hepburn[12]: The privy should be desludged every few years when the sludge layer reaches 4 inches of the outlet pipe, otherwise sludge will be carried over into the drainage field.

Iwugo et al.[16]: Many sewered aqua privies in Zambia have not been emptied for 18 years but continue to function properly provided they receive a liberal supply of water.

4.11.2 Discussion

Aqua privies in rural areas should be designed to last as long as possible as organised tank emptying facilities are unlikely to be available.

Privies in urban areas should be designed taking into account the emptying facilities that are to be provided. When a large number of privies are to be built mechanical emptying facilities will be required. To obtain maximum use from these emptying facilities it may be better to reduce the tank size which will also reduce construction costs.

Sludge build-up ratescan only be accurately determined by site measurements, but an initial design could be based on material given in Appendix II.

Consideration should also be given to the operational life of the effluent disposal system. Seepage pits and beds have a very variable working life, but if they are properly designed they will usually last between five and twenty years.

Evapotranspiration beds will require periodic crop replacement during which the bed will be out of commission.

Sand filters are usually operated in pairs so that they can be closed and cleaned alternately without closing down the system.

4.12 Problems

See section on Maintenance (4.9).

4.13 Details of References

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6. MacDonald, O.J.G., 1952. Small sewage disposal systems. Pub. John Wiley & Son, London.

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8. Ross Institute of Tropical Medicine, 1972. Rural sanitation in the tropics. Information and Advisory Service Bulletin No.8.

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11. Lumsden, L.L., Stiles, C.W., Freeman, A.W., 1915. Safe disposal of human excreta at unsewered homes. U.S. Public Health Bulletin No.68.

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16. Iwugo, K.O., Mara, D.D., Feachem, R.G. 1978. Sanitation site report No.4, Zambia. Appropriate technology for water supply and waste disposal in developing countries. A research project of the World Bank.

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18. Wagner, E.G., Lanoix, J.N., 1958. Excreta disposal for rural areas and small communities. W.H.O., Monograph No.39.

5.0 NIGHT SOIL CONSERVANCY SYSTEMS

5.1 Introduction

Conservancy systems of excreta disposal are of two types: bucket latrines and vault latrines.

Bucket latrines (Fig. 8)consist of a toilet sited over a small receptacle. This receptacle may be a bucket but it may equally well be an old battery case, empty oil tin or just a stone platform. The excreta are deposited directly into the receptacle which is regularly emptied, usually once every one or two days. In theory the receptacle should be taken away, emptied and cleaned before being replaced, but usually it is just emptied into a larger container and replaced uncleaned. The excreta are then carted away for final disposal. Emptying is usually done by hand and carting away may be anything from a sealed truck to an oil drum on the back of a cycle.

Vault latrines (Fig. 9) are toilets fitted to the top of a large watertight tank. Periodically (every 2-3 weeks) a vacuum tanker sucks out the vault contents and carts them away for disposal.

5.2 References for Design and Construction

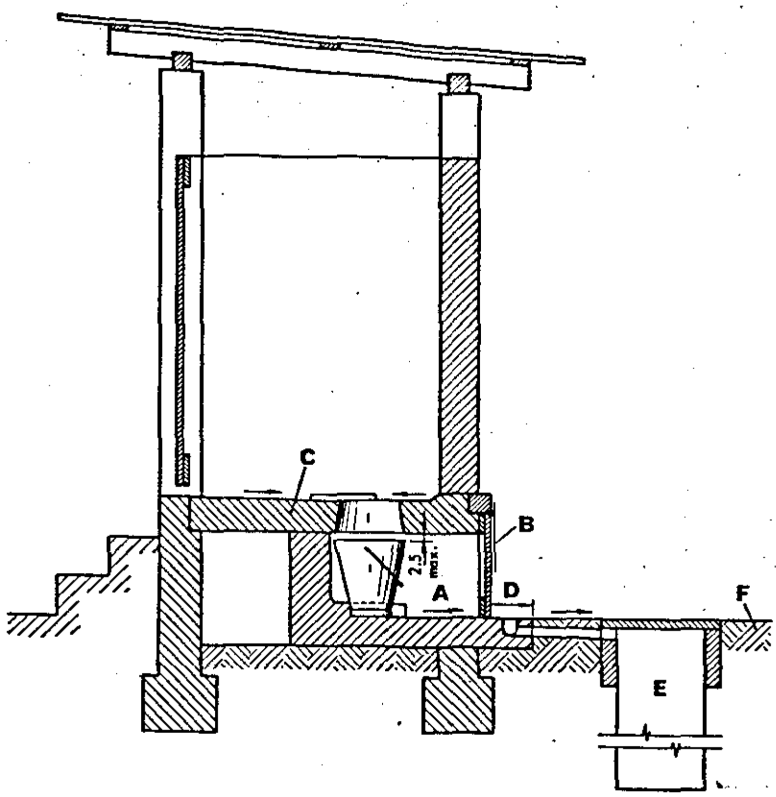
Bucket latrines. Wagner and Lanoix[1], Hardenbergh[3], Iwugo[16,17].
Vault latrines. Mara[2], Pradt[12], Shaw[19].

5.3 Terrain and Ground Conditions

5.3.1 References

Shelat and Mansuri[4]: Conservancy systems can be used where other systems cannot as, for example, high water table, unsuitable soil conditions, and the possibility of contaminating water sources.

Thomas[8]: Night soil collection is used for large areas of Taipei, Taiwan, where the flatness and low level frequently cause extensive flooding. The area also has a high perched water table and the ground is liable to subsidence.



The measurement shown is in centimetres.

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

Fig. 8. THE BUCKET LATRINE

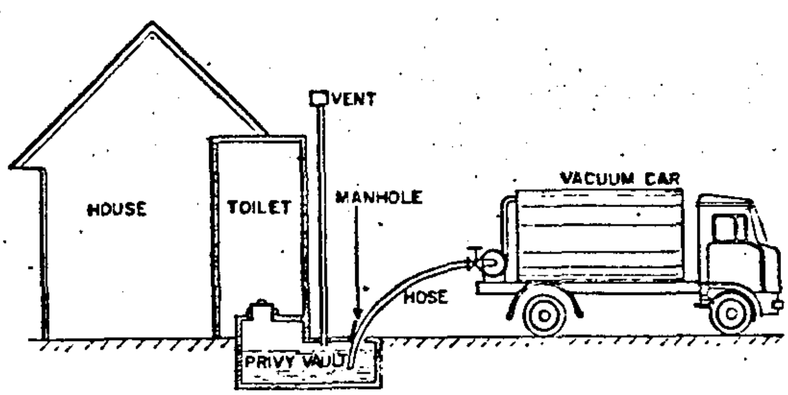


Fig. 9. THE VAULT LATRINE SYSTEM.

Ehlers and Steel[9]: Night soil systems are recommended where soil conditions are unfavourable for pit privies.

5.3.2 Discussion

Since the night soil is contained in a watertight vault or bucket its use will be independent of the ground conditions beneath the latrine. The system can also be used in areas subject to flooding provided the bucket is sited above maximum water level and is accessible whatever the water level.

Systems which allow for the leaching of the urine into the ground, however, cannot be used where there is a possibility of groundwater pollution or flooding.

Some of the night soil disposal systems such as composting and trenching can place a heavy pollution load on the ground and great care must be taken at these sites to guard against pollution of potable water sources.

5.4 Population Density

5.4.1 References

Wagner and Lanoix[1]: Bucket latrines are used in rural towns and urban areas without sewers in many countries of Africa, South-East Asia, and the Western Pacific.

Mara[2]: Suitable for urban areas.

Shelat and Mansuri[4]: Conservancy systems can be used where the proximity of housing prevents the use of other on site disposal methods.

Miller[7]: Night soil collection was the only form of sanitation in Lagos, Nigeria, which was very densely populated.

Thomas[8]: Nearly one-third of the population of Taipei, Taiwan, depend on daily collection for removal of their night soil.

Ehlers and Steel[9], Hardenbergh[13]: Suitable for unsewered sections of cities and small communities that do not have sewer systems. It is recommended however that it only be used as a temporary measure in rapidly developing towns unable to finance sewage works.

Pradt[12]: Night soil is collected in small trucks in order to negotiate narrow streets and alleys.

Collom[15], Iwugo[16,17]: Night soil collection is used in the very densely populated areas of Singapore, Ibadan, Nigeria, and Kumasi, Ghana.

5.4.2 Discussion

Night soil collection systems are very suited to high density urban areas when other sanitary systems would be technically unfeasible or uneconomic. They are also applicable as a temporary sanitary measure for rapidly expanding towns, or temporary housing schemes.

Vault latrines are most suited for dense urban areas provided there is sufficient room for the vacuum tanker to get near to the vault.

5.5 Water Supply

5.5.1 References

Ehlers and Steel[9], Hogg and Dyer[10], Wall[11]: Water is supplied where the buckets are washed and the trucks cleaned.

Pradt[12]: Night soil digestion requires the supernatant liquor to be diluted 20-40 times with fresh water.

Chemical treatment requires a dilution of at least 20 times and oxydation treatment requires a dilution of 20-40 times.

Iwugo[17]: Water is used for washing down the night soil tankers and cleaning the buckets between use.

5.5.2 Discussion

The bucket latrine system only requires the dwelling to have sufficient water available to keep the latrine clean. No extra water should be added to the bucket as this only makes the bucket heavier and more difficult to handle.

The toilet used in the night soil vault system is usually fitted with a water seal to prevent the odours from the vault entering the room. The water requirements of the seat are quite small (1-2 litres) but if it is not supplied the system will be objectionable.

Although little water is required at the dwelling large quantities will be required at the transfer station and disposal site to keep the system odour free and hygienic. The water for this task need not be treated provided it is fresh and fairly clean.

5.6 Acceptable Wastes

5.6.1 References

Wagner and Lanoix[1]: Some bucket latrines are fitted with a device that covers the excreta with dry earth, sawdust or ash, and others have a floor slab shaped so that urine and ablution water do not run into the bucket. In such cases the liquid is conveyed to either an impervious catchpit for further emptying or to a soakage trench.

Mara[2], Pradt[12]: Night soil only.

Miller[7]: In Lagos night soil contained a high proportion of leaves, rag and sticks.

5.6.2 Discussion

The night soil vault system is designed to receive faeces, urine, flushing water and soft anal cleansing material. Solid materials such as corn cobs, twigs, stones, etc. would not be acceptable as they would be difficult to remove from the vault and could damage the emptying tanker.

Most bucket systems only receive faeces, urine and all anal cleansing materials provided they are not too large or heavy. Areas where water is usually used for cleansing may require a more frequent emptying service or a smaller number of users per bucket than that required for other areas. In some areas ashes, dry earth or dust is sprinkled on the excreta after each use to deodorise the contents.

5.7 Pathogen Removal

5.7.1 References

Mara[2]: Because traditional methods of collection are usually so unhygienic it is probable that the system helps to spread infection.

In modern systems however the night soil is stored and transported in fully enclosed tankers and therefore avoids the health hazards associated with traditional methods.

Iwugo[16]: Night soil collection in Ibadan is very unhygienic. It is transported in open buckets and is frequently spilt in the process. Disposal is by trenching, which is done by hand, but the labourers are provided with no protective clothing, resulting in frequent direct contact with fresh excreta.

5.7.2 Discussion

Night soil conservancy systems, especially those of the bucket latrine type are often very unhygienic. The system is labour intensive and entails the frequent handling of fresh excreta. The excreta are often spilt in public places leading to cross infection within the community, attracting insects and rodents and causing bad odours.

Vault latrines are much safer because the excreta are transported mechanically so there is less chance of spillage or human contact.

5.8 Recoverable Material and Disposal

5.8.1 References

Wagner and Lanoix[1], Ehlers and Steel[9]: Discuss various methods of disposal.

Mara[2]: In Asia the demand for night soil is high for use as a fertilizer for vegetables, crops and fish ponds. In modern systems, however, the night soil is first pasteurised by high temperature steam before being used.

McGarry[3]: Night soil from Taiwan City, Taiwan, is used to fertilise approximately 6000 ha of fish ponds around the city.

Gotaas[5], McGarry[6]: Discuss methods of composting night soil with refuse.

Scott[14]: In North China the faeces are dried and sold as fertilizer.

Iwugo[16]: The trenching field used for disposal of the night soil is sometimes illicitly used for crop cultivation.

5.8.2 Discussion

Many of the processes used for the disposal of night soil produce some type of fertilizer. The form it will take and its quality will depend on its preparation and the materials with which it is combined.

5.9 Maintenance

5.9.1 References

Wagner and Lanoix[1]: The buckets are usually emptied daily. The pail should be fitted with a fly tight lid and replaced by a clean disinfected one of differing colour.

The method of transportation varies greatly among countries from the coolie 'bucket' system in the Far East to push carts or bull-carts and to motor vehicles elsewhere. Whichever method is used the bucket should be taken away and cleaned before being used again.

Mara[2]: Modern method of night soil disposal use a vented vault under a water seal toilet which only requires emptying every 2-3 weeks.

Ehlers and Steel[9]: Emptying should be regular preferably under supervision of the city authorities. It may be done weekly or at ten day intervals or even bi-weekly. The full bucket should be replaced by a clean one and the full one covered and taken away for emptying and cleaning.

Pradt[12]: In Japan night soil accumulates in vaults which are emptied every 3-4 weeks by small vacuum cars.

Scott[14]: In North China the faeces drop into a small sump from which they are removed, often daily, by a scavenger. The urine is allowed to seep into the ground. The scavengers take the faeces away in tubs on their backs or on long poles or in wheelbarrows.

Iwugo[16]: The household buckets have to be replaced about once a year and the district storage containers every five years. The collecting trucks require regular attention and have an average life of three years.

5.9.2 Discussion

Conservancy systems require good management and a great deal of maintenance to keep them operational and hygienic.

In the bucket system, toilet seats and doors have to be repaired frequently to keep them flyproof, buckets have to be emptied regularly and replaced frequently, and tankers must be maintained and repaired.

Vault systems depend even more on mechanised equipment which must be properly maintained to continue functioning.

5.10 Location

5.10.1 References

Ehlers and Steel[9]: Placing toilets at the fence line makes for speed in scavenging.

Wagner and Lanoix[1]: Most chambers open at the rear of the latrine into the service lane used for collection.

5.10.2 Discussion

The latrine should be located so that it is easily accessible from outside the property, preferably from a public highway.

Bucket latrines should preferably be placed away from the house and as far as possible from the kitchen so as to prevent nuisance from smells and contamination from flies.

Night soil vault latrines can be located inside the house provided the toilet is fitted with a water seal, is vented and is accessible to vehicles for emptying.

5.11 Working Life

5.11.1 References

Hardenbergh[13]: Metal night soil buckets usually last about one year. The main loss being due to corrosion rather than wear and tear.

5.11.2 Discussion

The system does not have a fixed lifespan but it is usually looked upon as a temporary measure until a better method can be installed.

The individual components such as buckets and transport do not have a very long life due to the rough handling that they receive and the corrosiveness of the night soil.

5.12 Problems

5.12.1 References

Wagner and Lanoix[1], Mara[2], Iwugo[16]: Although technically feasible, satisfactory conservancy systems anywhere in the world are rather rare exceptions. Although cheap to install they are the most expensive to operate. They are a health hazard for the community, especially the scavengers, as well as leading to social difficulties for the collectors.

The contents are usually highly odorous and attractive to flies which easily gain access because the collection chamber and seat are seldom flytight. Despite active supervision the bucket contents are often spilt. The bucket lids are rarely kept in place and in some towns the buckets are left on the sidewalks for many hours awaiting collection.

Systems that depend on separation of urine are seldom built and maintained properly,as a result the urine runs over soaked ground through unsightly pools.

Conditions at disposal sites are often intolerable due to spillage, lack of an abundant water supply, fly breeding, odours and rodents.

Mara[2]: In modern systems the night soil is contained in vented vaults fitted with a water sealed toilet and emptied by vacuum suction into an enclosed tank. The system is free from odour and avoids hazards from spillage and insects.

Thomas[8]: An extensive study of the night soil problem in Taipei indicated that unscreened or poorly screened latrines were a prolific source of fly breeding.

Pradt[12]: The vacuum car, if in good condition, gives off no odours; the process of removing the contents of the customer's privy is however sometimes rather offensive. Some of the purification processes used also produce offensive odours.

Hardenbergh[13]: Even the best designed latrine is rarely flyproof for more than 6 months. Bucket covers are rarely efficient.

Scott[14]: During the fly season the exposed faeces in the latrines and at the drying ground are a breeding ground for flies. There is also a bad smell in the proximity of the drying grounds. Much pollution is caused in the city by careless collection and transportation of the faeces.

5.12.2 Discussion

Night soil collection systems are well known for being unhygienic, smelly, dirty and degrading for the operatives. A great deal of the problems are due to poor management, lack of maintenance and lack of money; but even with a highly mechanised efficient system there are still problems involved with this method of sewage disposal which makes it less preferable than most other methods.

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13. Hardenbergh, W.A., 1924. Home sewage disposal. Pub. J.B. Lippincott Co., U.S.A.

14. Scott, J.C., 1952. Health and agriculture in China. Pub. Faber & Faber Ltd., London.

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16. Iwugo, K.O., Mara, D.D., Feachem, R.G., 1978. Sanitation site report No.1, Ibadan, Nigeria. Appropriate technology for water supply and waste disposal in developing countries. A research project of the World Bank.

17. Iwugo, K.O., Mara, D.D., Feachem, R.G., 1978. Sanitation site report No. 3, Kumasi, Ghana. Appropriate technology for water supply and waste disposal in developing countries. A research project of the World Bank.

18. Pescod, M.B., 1970. Wastewater solids utilisation and disposal in tropical developing countries. Proceedings of seminar on water supply and sanitation in Bangkok, 19-23 Jan. Ed. M. Pescod, D.A. Okun, Pub. Asian Institute of Technology.

19. Shaw, V.A., 1962. A system for the treatment of night soil and conserving tank effluent in stabilisation ponds. Council for Scientific and Industrial Research, South Africa. Reprint Paper No. RW 166.

SECTION 2: SELECTING A SANITARY SYSTEM

6.0 EXPLANATION OF TERMS

6.1 Introduction

The choice of the most appropriate sanitary system for a particular site will depend upon the conditions prevailing at that site and the characteristics of the individual systems.

The characteristics of the sanitary systems have already been fully discussed in Section 1, but it is still necessary to discuss the controlling site conditions.

The site conditions that will control the selection of a sanitary system may be divided into two categories: physical conditions and socio-economic conditions.

6.2 Physical Conditions

Physical conditions are those that are independent of social and economic pressures and include the following.

Ground conditions: This refers primarily to the type of ground existing within the top 5-10 metres. The terrain, within the normal limits of human habitation, has little effect on the operation of sanitary systems.

Water table: The maximum level achieved by the groundwater (or flood water) is the controlling level. It also includes temporary perched water table levels.

Temperature: Low temperatures affect the operation of some sanitary systems although most can withstand low temperatures for a short time. The minimum mean monthly air temperature is probably a reasonable figure on which to base any decisions.

Population density: Definitions of population density are fairly arbitrary but in most cases self-explanatory. The difference between urban and high density may, however, not be as clear. For the purposes of the report high density urban areas are those where properties have no open land that is not in constant necessary daily use. The definition does not consider cultivated land as being necessary use.

Water supply: This refers to the normal quantity of water entering a dwelling per person per day that is not used for drinking purposes.

Wastes to be disposed: A realistic decision should be made about the types of waste that are likely to be disposed of in the latrine.

6.3 Socio-Economic Conditions

The socio-economic conditions are those imposed by the society for which the sanitary system is intended. Their effect on the choice of a sanitary system cannot be defined like the physical conditions because their value and relative importance will vary with different sites. The important conditions are as follows.

Similarity to existing sanitation: This may be an advantage or a disadvantage, depending on the feelings of the populace.

Construction cost: This is a relative factor between different sanitary systems and its importance to the final choice will also be relative, depending on the ease of obtaining capital.

Running costs: Also a relative factor between different systems.

Acceptability: It does not matter how good a latrine is if no one can be persuaded to use it!

Disturbance: Installation or operation of some systems may create so much physical, economic or social disturbance that it might be considered unsuitable.

Ease of operation and maintenance: this will depend on whether the society has a strong municipal authority, an educated populace, skilled labour, access to mechanical equipment and spares, etc. More detailed information on this topic is given in Chart 2.

7.0 EXPLANATION AND USE OF SELECTION CHARTS

7.1 Introduction

The information obtained in Section 1 on the different sanitary systems is summarised in this chapter in chart form. At the same time it has been transposed so as to be of more practical use to anyone trying to select a sanitary system for a particular site.

Three charts are provided, Charts 1 and 2 are for making the selection and Chart 3 for supplying supporting information.

7.2 Chart No.1

Physical Conditions Affecting the Selection of a Sanitary System

Determine which of the conditions given on the chart most closely resemble those prevailing on the site under consideration. For each condition chosen, check across the chart and see which system(s) will operate. It will thus be possible to determine which sanitary systems have operating conditions that most closely resemble those prevailing on the site under consideration.

The information given in the chart is cross-referenced with the appropriate source in the text. The chapter number is given at the top of the columns and the section of each chapter on the righthand side of the chart. Example: Further information about bored hole latrines in gravelly ground will be found in Chapter 2, section 3 i.e. look in text at 2.3.

7.3 Chart 2

Socio-Economic Conditions Affecting the Selection of a Sanitary System

Fill in the names of the sanitary systems that will operate under the prevailing site conditions across the top of the chart in the space provided. Determine the relative importance of the conditions mentioned on the lefthand side of the chart and fill in the weights accordingly. For example, if 'acceptability' is twice as important as 'running costs' then if the weight for 'running costs' is 5 then the weight for 'acceptability' will be 10. The weight will be the same for all the systems for the same condition.

Fill in the number between one and five in the squares provided, the most favourable system for the condition receiving the highest number. For example, if the construction cost of pit latrines and aqua privies was being compared and pit latrines were the cheapest, then a higher number would be given for pits than for aqua privies. The highest number should always be a 5.

When all of the tables has been filled in, multiply the numbers by the weights below them and then total each column. The column with the highest total is the most suitable sanitary system.

7.4 Chart 3

Operating Characteristics of Sanitary Systems

This chart provides information to assist in the compilation of Chart 2.

		PIT LATRINE			BOREHOLE LATRINE		COMPOSTING TOILET					AQUA PRIVY					NIGHT SOIL SYSTEM			SECTION
		Standard	P.R.A.I.	R.O.E.C.	Standard	Water Seal	Anaerobic Pit	Double Vault	Vietnamese Double Vault	Mouldering	Mouldering With Drain	Seepage Pit	Percolation Field	Sewered	Evapotranspiration Bed	Sand Filter	Standard Bucket	Leaching Pit	Vault	
	Chapter	1	1	1	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	
GROUND CONDITIONS	Gravel	a	a	a			a	*	a	*	a	a	a	*	a	*	*	a	*	3
	Fissured	b	b	b	b	b	b	*	b	*	b	b	b	*	b	*	*	b	*	
	Permeable	a	a	a	a	a	a	*	a	*	a	a	a	*	a	*	*	a	*	
	Rocky	a	c	a			c	*	a	*	c	d	d	*	a	*	*	c	*	
	Impermeable	*		*	*		*	*	*	*				*	*	*	*	*	*	
WATER TABLE	Low	f	f	f	f	f	f	*	f	*	f	f	f	*	f	*	*	f	*	3
	High	a	a	a	a	a	g	*	a	*	h	a	a	*	a	h	*	a	*	
	Subject to flooding	j	j	j	j	j	gj	k	h	k	h						h	he	k	
TEMPERATURE	Above 10°C	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3
	0 - 10°C	*	*	*	*	*						*	*	*	*	*	*	*	*	
	Below 0°C	m		m	*							m	m	m		m	*	*	*	
POPULATION DENSITY	Rural	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4
	Village	f	f	f	f	f	f	*	f	*	f	f	f	*	f	*	*	f	*	
	Sub-urban	f	f	f	f	f	fn	fn	fn	n	fn	f	f	*	f	*	*	f	*	
	Urban	f	f	f			fn	fn	fn	n	fn	f	f	*			*	f	*	
	High density urban													*			*	f	*	
WATER SUPPLY	None	*		*	*		p	p	p	p	p						*	*	*	5
	0-2 litres/Cap./day	*	*	*	*	*	*	*	*	*	*						*	*	*	
	More than 2 litres/Cap./day	q	q	q	q	q	q	r	r	r	r	*	*	*	*	*	r	r	r	
WASTES TO BE DISPOSED	Faeces	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6
	Urine	*	*	*	*	*	*	*	t	*	*	*	*	*	*	*	*	t	*	
	Anal cleansing water	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
	Anal cleansing tissue	*		*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	
	Other cleansing material	*		*	*		u	u	u	*	*	*	*	*	*	*	*	*		
	Refuse bio-degradable	v		v			*	*	*	*	*									
	Sullage	c	c	c	c		c					*	*	*	*	*				

CHART 1 PHYSICAL CONDITIONS AFFECTING THE SELECTION OF A SANITARY SYSTEM

Key to chart given overleaf

Key to Chart No.1

General

*	The sanitary system mentioned directly above it will operate under that condition.
'm'	or any other letter indicates that the system mentioned above it will operate under that condition with certain provisions. The provisions are detailed below.
Blank	indicates that the system mentioned directly above it will not operate under that condition.

Provisos

a	Provided there is no possibility of polluting local water sources. (see Appendix 1).
b	Only if full area of underground pollution is known, or the ground does not contain potable water. (see Appendix 1.).
c	Provided the ground is permeable and then check for pollution of water sources. (see Appendix 1).
d	If the soil cover is greater than 1 metre. Check for pollution of water sources.
e	Only if urine is collected in watertight containers for offsite disposal (see chapter 5).
f	If large numbers of leaching systems in a small area, check for chemical groundwater pollution, especially nitrates. (see Appendix 1,3).
g	Contents liable to be liquid. Check for pollution of water sources (see Appendix 1).
h	Only if bottom of container is above maximum water level. Check for pollution of water sources (see Appendix 1).

j Provided pollution of surface water is prevented. Check for pollution of water sources (see Appendix 1).

k Provided all openings above maximum water level.

m Not if fitted with waterseal latrines (Chapter 1.3).

n Only if gardens are normally cultivated or fertilizer is in demand.

p May require the addition occasionally of a small quantity of water if the vault walls are very permeable, or in a hot and arid climate.

q Provided the ground is permeable enough to accept it.

r Only sufficient water for anal cleansing should be deposited.

s Fouling may occur if faeces are soft.

t Urine is collected separately.

u If bio degradable.

v Provided the pit is designed to accommodate it.

SYSTEMS TO BE CONSIDERED →

FACTORS ↓						
SIMILARITY TO EXISTING SANITATION						
WEIGHT						
CONSTRUCTION COST						
WEIGHT						
RUNNING COST						
WEIGHT						
ACCEPTABILITY						
WEIGHT						
DISTURBANCE						
WEIGHT						
EASE OF OPERATION AND MAINTENANCE						
WEIGHT						
TOTAL						

CHART 2 SOCIO-ECCONOMIC FACTORS AFFECTING THE CHOICE OF A SANITARY SYSTEM

		Pit Latrine			Borehole Latrine		Composting Toilet					Aqua Privy					Night Soil System			
		Standard	P.R.A.I.	R.O.E.C.	Standard	Water Seal	Anaerobic Pit	Double Vault	Vietnamese Double Vault	Mouldering	Mouldering With Drain	Seepage Pit	Percolation Field	Sewered	Evapotranspiration Bed	Sand Filter	Standard Bucket	Leaching Pit	Vault	SECTION
	Chapter	1	1	1	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	
PATHOGEN TRANSMISSION CONTROL	Good	•	•	•		•				a		•	•	•		•			•	7
	Fair				•		•	•			•				•	•				
	Poor								•								•	•		
RECOVERABLE RESOURCES	None				•	•														8
	Occasional	•	•	•								•	•		•	•				
	Regular (Every 6-12m)						•	•	•	•	•			b						
	Continuouse																b	b	b	
LOCATION	Inside House		c							d	d	e	e	e	e	e			e	10
	Adjacent To House	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	
	Separate From House	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
WORKING LIFE (Between major mainte--nance.)	6-12 months						•	•	•											11
	1-5 Years				•	•									•	•				
	5-10 Years	•	•	•	•	•						•	•	•	•	•				
	10-20 Years	•	•	•								•	•	•		•				
	Above 20 Years									•	•						•	•	•	
OPPERATING DIFFICULTIES (Poorly mntd.)	Minimal	•	•	•		•														12
	Frequent				•							•	•	•	•	•				
	Very Frequent						•	•	•	•	•						•	•	•	
USER INVOLV-EMENT IN OPERATION	Occasional	•	•	•	•	•						•	•	•		•	•	•	•	9
	Regular-Simple																			
	Regular-Complex						•	•	•	•	•				•					
OFF SITE MAINTENANCE	Nil	•	•	•			•	•	•	•	•									9
	Occasional				•	•						•	•		•	•				
	Regular-Simple													•						
	Regular-Complex													•			•	•	•	
USER TECHNIC--AL SKILLS	Minimal	•	•	•	•	•						•	•	•		•	•	•	•	9
	Appreciable						•	•	•	•	•				•					
OFF SITE TECHNICAL SKILLS	Minimal	•	•		•	•	•	•	•	•	•									9
	Appreciable			•								•	•		•	•	•	•		
	Considerable													•			•	•	•	
OFFSITE MAINTENANCE MACHINERY	None	•	•	•			•	•	•	•	•									9
	Low Technology				•	•						•	•	•	•	•	•	•		
	High Technology											•	•	•	•	•	•	•	•	

CHART 3 OPERATING CHARACTERISTICS OF SANITARY SYSTEMS

Key to chart given overleaf

Key to Chart No.3

General

*	The sanitary system mentioned directly above it has that operating characteristic.
'e'	or any other letter indicates that the system has that operating characteristic with certain provisions. The provisions are detailed below.

Provisos

a	If ponding occurs - only 'fair'.
b	Resources not recovered by householder.
c	Latrine only, not pit.
d	Not recommended in the tropics because of possible smell and flies.
e	The tank must be accessible for emptying from outside the dwelling.

APPENDICES

APPENDIX 1

A.1 The Travel of Pollution Underground

A.1.1 Introduction

Many of the sewage disposal systems discussed in this report rely to some extent on infiltration of part of the sewerage into the surrounding ground. The infiltrated matter will have a very high organic and chemical content as well as containing pathogenic organisms. It is therefore necessary to determine how far the pollution is likely to travel in the ground so that possible pollution of potable underground water sources can be prevented. The pollution can be divided into three sections: bacterial, chemical and viral, and there now follows a resumé of the information available on each section.

A.1.2 Bacterial Pollution

References

Caldwell[1]: Bacterial pollution flow from a pit latrine entering the water table never exceeded 10 ft and at the end of the test had regressed to 5 ft. The stream, which only travelled in the direction of groundwater flow, never exceeded a width of 5 ft, or a depth of 3 ft, and by the end of the experiment was less than 1 ft wide and 6 inches deep. Groundwater flow rate was 1-2 ft/day.

Caldwell[2]: In a similar experiment to the one above, but in groundwater having a flow of 13.3 ft/day, pollution reached 80 ft.

Caldwell[4]: In another experiment pollution from a pit varying from 4in-2f above the water table did not travel 5 ft.

Tests carried out with the water table 12 ft below the pit found that pollution did not travel 1 ft vertically or horizontally when only faeces and urine were deposited. If rainwater was also allowed to enter E.Coli were found 3 ft but not 4 ft below the pit and 1 ft horizontally and if an additional 100 gallons of water were put in the pit per day the bacteria travelled 6 ft but not 7 ft vertically and 3-4 ft horizontally. In all cases, as the pit matured, the pollution flow regressed considerably.

Caldwell[5]: When a pit in highly permeable ground was surrounded by a layer of fine sand the pollution flow was restricted to less than 10 ft. A similar pit without the envelope of fine sand created bacterial pollution 80 ft from the pit.

Kligler[9]: Tests on the soil surrounding a pit latrine above the water table showed that pollution did not enter more than 3 ft vertically or 1-2 ft horizontally during the dry season, but during the rainy season lateral pollution increased to 5 ft.

Experiments on septic tank drainage fields indicated the E.Coli were not present 5 ft from the sewer in dry ground but could travel 18 ft in water bearing strata.

Caldwell and Parr[3]: Bacterial contamination from a bored hole latrine varies according to the rate of groundwater flow. At a flow of 5-8 ft/day E.Coli reached 35 ft from the hole, and at a flow of 3 ft/day they failed to reach 15 ft. The width of the pollution did not exceed 3 ft and it travelled in the direction of groundwater flow. By the end of the observation the bacterial stream had regressed to practically within the hole.

Yeager[7]: A bore hole innoculated with a single does of E.Coli created pollution 70-100 ft away in all direction. The ground was very permeable but groundwater flow was negligible.

Dyer and Bhaskaran[10]: A similar experiment to that carried out by Caldwell and Parr[3], but with groundwater flow rate of 2½ ft/day, observed pollution to travel 10 ft.

Baars[6]: Infiltration of moderately polluted water through fine grained sand at a rate of 0.8 m/day showed that E.Coli were removed in

3 metres. When the sand bed had matured they were removed in 1.5 m.

Stiles and Crowhurst[8]: Excreta infiltrated into groundwater from trenches was observed to produce pollution 65 ft away. The pollution travelled in a thin sheet on top of the groundwater with little dispersion.

Butler et al.[13]: All coliforms were removed from water, settled primary effluent and final effluent after infiltrating them through 4 ft of fine grained soils.

In another experiment it was proved that as the effective grain size of the soil increased the efficiency as a bacterial filter decreased. It was also noticed that most of the organisms were removed in the first 5 mm of the soil by an organic mat.

As a third experiment diluted primary settled sewage was injected into an aquifer. Bacterial pollution was observed 110 ft away after 33 hours but did not reach 246 ft.

Gotaas et al.[14]: Diluted sewage injected into an aquifer travelled 100 ft in the direction of groundwater flow and 63 ft opposite groundwater flow.

Reneau and Pettry[11]: Tests on three existing septic tank drainage fields to determine the extent of bacterial pollution obtained variable results. One field discharging 46.7 $l/m^2/day$ produced pollution 6.1 m from the sewer, another discharging 7.2 $l/m^2/day$ extended 13.5 m and another discharging 16 $l/m^2/day$ extended 30 m. All soil conditions were similar but no information was given on groundwater flow rates.

McFeter et al.[12]: Investigation on the half life of pure cultures of pathogens and indicator bacteria in clear well water indicate that some pathogens (mainly shigella) may survive longer than E.Coli.

A.1.3 Chemical Pollution

References

Caldwell[1]: Chemical pollution from a pit latrine entering the water table was traced 325-350 ft from the pit. The width of the slick reached 25 ft before gradually tapering off, and it extended to the full depth of the aquifer (7 ft) for the first 80 ft and then gradually tapered out from the bottom so that the top level remained constant. The velocity of the groundwater was 1-2 ft per day. No indication was given if the pollution slick was still advancing at the end of the experiment.

Caldwell and Parr[3]: A bored hole latrine daily receiving faecal material chemically polluted the groundwater to a distance exceeding 85 ft in one year. The maximum width of the pollution was 5 ft, 25 ft from the hole. The maximum value for nitrate concentration recorded was 0.95 p.p.m. 35 ft from the hole. By the end of the experiment the pollution flow had weakened but not regressed.

Dyer and Bhaskaran[10]: Chemical pollution from a bored hole latrine entering the groundwater was observed to travel 15 ft before becoming untraceable. The groundwater velocity did not exceed 2½ ft/day.

Lang and Bruns[18]: A leaky sewer carrying effluent at a sewage treatment works caused phenol tastes and fungi growth in wells 300 ft away. Flouresin put in the sewer showed up at the well in 24 hours.

Dapport[19]: Sewage effluent infiltrated into the soil over a 5 acre site caused chemical pollution of the groundwater for a distance exceeding 1500 ft. The width of the slick reduced from 2000 ft to 200 ft in the first 1000 ft and then remained constant until it outcropped 500 ft away.

Stiles and Crowhurst[8]: Excreta deposited in a trench entering the groundwater caused chemical pollution 115 ft away in 187 days.

Schroepfer and Preul[34]: An investigation from existing drainage fields of septic tanks in homes and schools observed nitrate values of up to 40 mg/l, 20 ft from the release point, but by 100 ft all values were below 10 mg/l.

Baars[6]: Tests on ground around disused bored hole latrines above the water table showed a gradual decline in the total nitrogen.

In another experiment mildly polluted effluent infiltrated through 460 ft of dune sand in 100 days reduced the nitrate level from 6.2 p.p.m. to a trace.

Behnke and Hartell[15]: Measurements of nitrates concentration in groundwater below a sewage farm and a housing site having individual septic tanks showed a marked increase from 11-15 p.p.m. even though the groundwater table was 70 ft below ground level. Samples from disused wells in the area showed that most of the pollution was in the top 10 ft of the aquifer.

Schmidt[16]: A more detailed survey of the site tested by Behnke and Hartell found that the highest nitrate concentrations occurred when the ground had low porosity or where septic tanks had been in use for a long time. It was also found that the pollution was confined to the top 60 ft of the aquifer.

Hutton et al.[17]: Studies on water supplies serving most major towns in Botswana indicated numerous instances of high nitrate pollution. Although much of the pollution was caused by poor hygiene at the well some was thought to have been caused by septic tanks and pit latrines within the towns.

Lewis et al.[37]: Further to observations made by Hutton et al. experiments carried out on one of the boreholes discovered that the aquifer and surrounding pit latrines entered fissured rock of low permeability so that when the borehole was pumped at 1 l/s pollution was travelling 20 ft through the ground in 200 mins.

Further tests determined that nitrates from pit latrines sited above groundwater level were being washed into the groundwater by rainwater.

A.1.4 Viral Pollution

References

Drewry and Eliassen[20]: Five columns of widely varying types of soils inundated continuously for over 500 hours with distilled water containing two types of culture-grown bacterial virus (T1 and T2) removed over 99% of the viruses with most of the removal taking place in the first few centimetres. Flow rate through the soils varied from 0.175 - 0.702 m/day.

Robeck et al.[21]: 2 ft columns of clear sand inundated with clean water containing polio viruses at various rates of flow up to 4 ft/day achieved 99.99% removal of viruses, but with higher flow rates the percentage removal gradually decreased.

Romero[22]: Studies performed for the U.S. Dept. of the Army have indicated that sands ranging from fine clayey sand to coarse granite alluvium containing viruses are more effectively retained in the finer sands, particularly if they contain relatively high percentages of clays and silt. Virus removal was shown to increase with decreasing particle size and the greatest percentage removal took place in the uppermost portion of the soil. It was shown that 2 ft of well sorted sand of average size 0.16 mm could remove 99.999% of viruses.

University of California (from Romero)[23]: 12 litres of concentrated polio vaccine virus type 3, was mixed with 10 gallons (U.S.) of unchlorinated water and applied to a percolation bed influent over a period of 3 hours. A sampling well 200 foot away downstream failed to locate any viruses. The soil was an old stream bed consisting of fine sands to coarse gravels.

Neefe and Stokes[24]: An outbreak of infectious hepatitis was traced back to a polluted well. The well, 220 ft deep, was polluted from a cesspool known to contain faeces from infected persons 150 ft away, 6 to 8 ft below the ground. All other possible methods of infection were checked and found to be highly unlikely.

The ground consisted of 4 - 6 ft of top soil overlying a layer of hardpan which overlaid bedrock. The nature of the bedrock was not determined but was thought to consist of red shale and limestone. In nearby areas where the rock outcropped it was found to be highly fissured.

A.1.5 <u>Discussion and Conclusions</u>

Bacterial pollution flow from subsurface pollution sources below the water table is in the direction of groundwater flow. However it should be remembered that the direction of flow can be altered by the abstraction of water from boreholes. The flow tends to undergo very little lateral dispersion and tends to stay at the level it is introduced into the soil. Bacteria will travel further in strata with higher groundwater velocities and from sources of higher surface areas.

Present information indicates that bacterial pollution is unlikely to travel further than 30 metres in granular soil provided it is introduced into the groundwater at normal pressures. When the source is injected under pressure into the aquifer, however, there is a possibility that the pollution will travel further. If groundwater velocities are within normal limits (less than 3.5 m/day) and the ground is fine grained then bacterial pollution travel is unlikely to exceed 5 metres. If the direction of groundwater flow is unknown then bacterial pollution should be assumed within a 30 m radius of the source; but if the groundwater velocity is known to be negligible then the radius can be reduced to 25 m.

Continuous pollution from a source produces a defence mechanism within the soil which tends to reduce the zone of pollution. This reduction varies according to the conditions but it can be appreciable. It is not recommended that this reduction be taken into account, however, as any sudden rise in the water table may introduce pollution into an undefended soil zone.

Pollution flow in fissured ground travels along the fissures rather than through the ground. Such pollution flow is unpredictable and can be considerable (several miles), and it is therefore not recommended that human wastes be disposed into them unless it is absolutely sure that the polluted water will not be used for human consumption without treatment.

Since pollution must be transported through the soil by water, sources sited above the water table will produce much less pollution. Bacterial pollution from pit and borehole latrines receiving only excreta and urine will not exceed 1 m vertically and 0.6 m horizontally. If the pit receives sullage or is open to the elements it may reach 1.3 m vertically and 1.6 m horizontally. Effluent from cesspits, septic tank drains, etc. may extend 2.2 m vertically and 1.3 m horizontally.

Chemical pollution flow in groundwater is similar to bacterial pollution flow except that it tends to disperse more, both vertically and horizontally, and travels much further. Unlike bacteria, the chemicals are not destroyed in the ground but are gradually diluted by the groundwater therefore the distance they travel is governed by the dilution rate rather than their destruction rate. The distance the pollution will travel before being fully diluted will depend on many factors but primarily on the groundwater velocity and the quantity of pollution discharged. Larger pollution sources will travel further and high groundwater velocities will more quickly reduce the pollution strength.

Chemical pollution sources located above the groundwater are no less a danger than those in it since the chemicals will eventually be washed into groundwater by rainwater.

A pit latrine or septic tank situated a safe distance bacterially upstream from a well or borehole may cause objectionable smell or taste in the water but is seldom dangerous. If a number of latrines, however, are located in the area there is a possibility of dangerously high nitrate levels building up immediately downstream.

Information available to date (mainly from laboratory experiments) indicates that viruses are likely to be removed from groundwater faster than bacteria. Therefore water sources protected from bacterial pollution are unlikely to suffer from viral pollution.

A.2 Quantities of Human Faeces

A.2.1 Fresh Faeces and Urine

A summary of information on this topic is given in Table 1.

Volumes of faeces and urine vary considerably throughout the world depending on water consumption, occupation, diet, etc. and the only accurate way of determining volumes for particular places is by direct observation. In the absence of local information the following are suggested for design purposes.

Temperate climate:	Faeces	0.12	litres per person per day
	Urine	1.2	ditto
Tropical climate:	Faeces	0.4	ditto
	Urine	1.0	ditto

A.2.2 Volumes of Digested Human Wastes

As faeces consolidate and digest they reduce in volume. Little information is available about the rate at which the faeces digest especially in on-site disposal systems in the tropics, but Weibel et al.[40] have measured the sludge accumulation rate in septic tanks in the U.S.A. and in the absence of any more accurate information it is suggested that their figures be used (Table 3).

For the design of on-site collection and disposal systems where the contents are to be stored for many years the terminal volume of the digested matter is of more importance than the rate of digestion. A summary of available information on this topic is given in Table 2. The volume will vary according to the specific site conditions and the only way to obtain accurate information is to take direct measurements in the locality where the new facilities are to be provided. In the absence of such local information the following figures are recommended:

Below water with bio degradable anal cleansing materials	0.04 metres^3 per caput per year
Below water with non degradable anal cleansing materials	0.06 metres^3 per caput per year
Dry conditions with bio degradable anal cleansing materials	0.06 metres^3 ditto
Dry conditions with non degradable anal cleansing materials	0.10 metres^3 ditto

TABLE 1 Daily production of faeces and urine per person for different locations.

Location	Daily production of faeces and urine per caput Grams	Litres	Remarks	Reference
Japan		1.0–1.1	Faeces and urine	Pradt[35]
Asia	200–400	0.2–0.4 *	Wet weight (faeces?)	Wagner & Lanoix[25]
Europe & America	100–150	0.1–0.15*	Wet weight (faeces?)	ditto
Philippines	665	0.65 *	Probably includes only a fraction of urine	ditto
General		1.0–2.0	Night soil	Mara[26]
South Africa		1.0	Night soil	Shaw[27]
General	135–270	0.13–0.25*	Wet weight (faeces?)	Gotaas[28]
General		1.0–1.3	Urine only	Gotaas[28]
Europe	113–128	0.11–0.12*	Faeces only	MacDonald[29]
India	284–539	0.28–0.53*	Faeces only	MacDonald[29]
India	255	0.25 *	Faeces - average for family incl. children	MacDonald[29]
Temperate climate		1.42	Urine	MacDonald[29]
Tropics		0.71–1.22	Urine	MacDonald[29]
China	209	0.2 *	Faeces - men on light labour	Scott[38]
Urban Scotland	80	0.08 *	Faeces	Eastwood[39]
Rural Africa	500	0.49 *	Faeces	Eastwood[39]

* Converted from given weight using density 1025 kg/m^3 (64 pounds/ft^3): Gotaas[28].

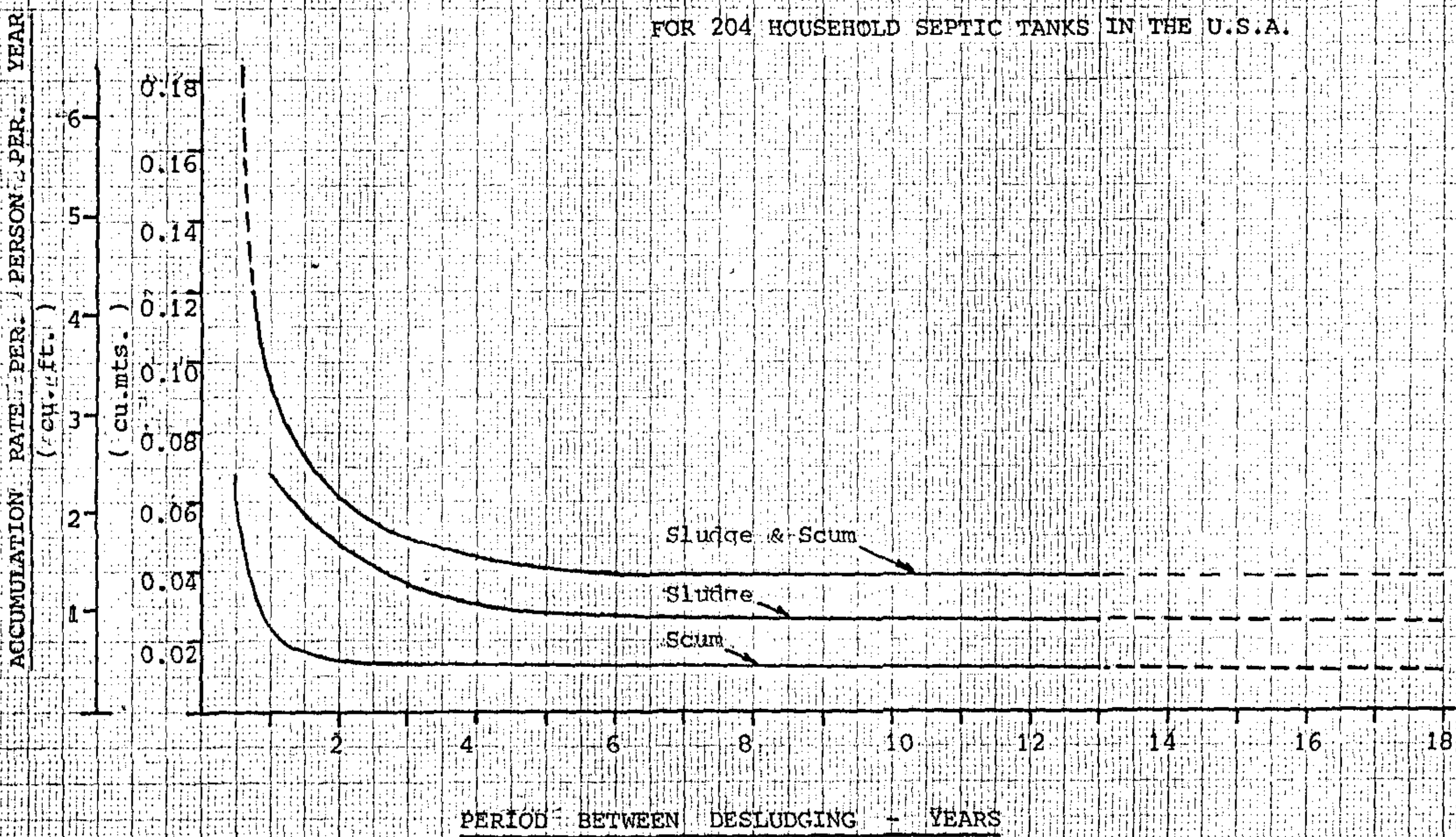
TABLE 2 Yearly volumes of fully digested human wastes.

Place	Yearly volume of faeces per caput (m^3)	Remarks	Reference
Philippines	0.04	Wet pit - degradable cleansing materials	Wagner and Lanoix[25]
Philippines	0.06	Dry pit - degradable cleansing materials	ditto
West Bengal	0.025	Wet pit - ablution water used	ditto
West Bengal	0.034	Wet pit	Bhaskaran[30]
India	0.126	Including sullage - figure varies depending on soil	Kharkar et al.[31]
Brazil	0.047	Dry pit	Sanches and Wagner[32]
West Bengal	0.025-0.036	Sludge build-up in aqua privy	Majumdar et al 33.
U.S.A.	0.042	Faeces only (adult), half amount for children	Fair and Gayer[36]

TABLE 3

AVERAGE RATE OF SLUDGE AND SCUM ACCUMULATION

FOR 204 HOUSEHOLD SEPTIC TANKS IN THE U.S.A.



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APPENDIX 3

Bibliography of Unquoted References

The preparation of this report entailed the acquisition and reading of a large number of books, periodicals and papers which were found to contain no pertinent information. For the purposes of completeness a list of the unquoted references now follows. The references are given in alphabetical order of the authors and their application is indicated by a key at the end of each reference.

Key

P Pit latrines

B Bored hole latrines

C Composting latrines

A Aqua privies and septic tanks

N Night soil conservancy systems

G Travel of pollution underground

Q Quantities of human faeces

M Bio-gas plants

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