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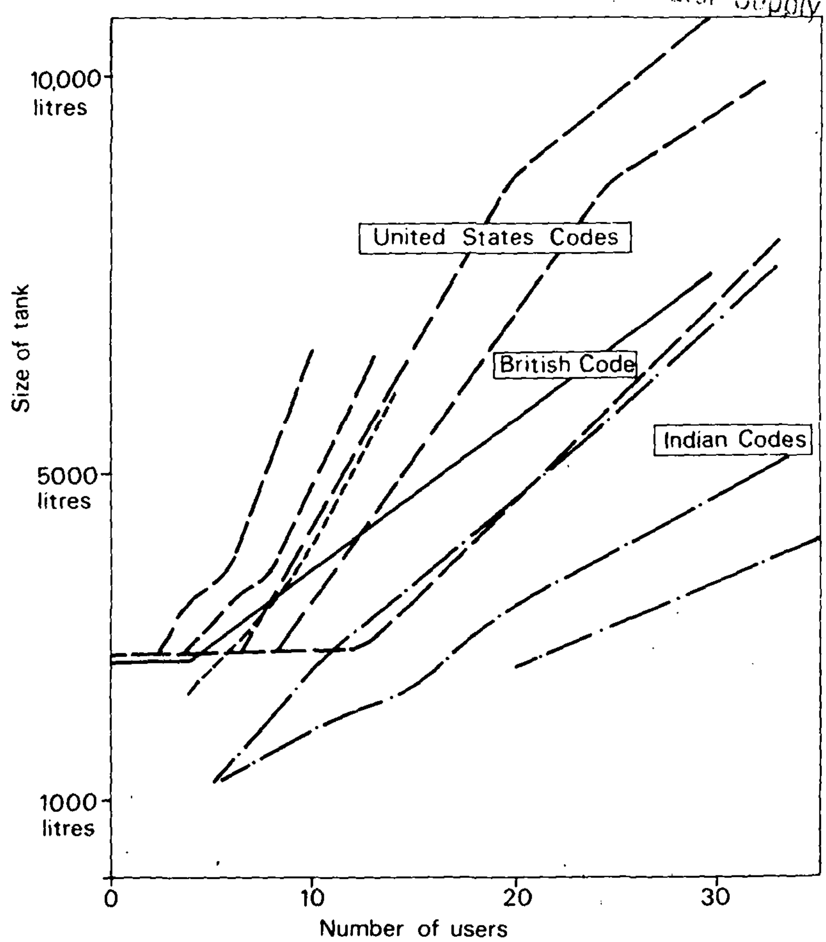
THE DESIGN OF SEPTIC TANKS AND AQUA-PRIVIES

By John Pickford



Various formulae have been used, by different regulatory bodies, to calculate the effective capacity of small septic tanks

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BIOGRAPHICAL NOTE

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OVERSEAS BUILDING NOTES

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FOREWORD

An earlier Overseas Building Note (No 168, June 1976) reviewed low cost sanitation systems that are not dependent upon sewers for disposal of the wastes.

Brief descriptions were given of both the 'Septic Tank' and the 'Aqua-Privy', together with an outline of the principles to be adopted in their design and construction.

The present note gives a more complete description of the processes involved in these systems, and sets down the calculations needed to ensure an efficient and economical size of tank for particular circumstances.

CONTENTS

1 INTRODUCTION

A major factor influencing the health of individuals and communities is the proper disposal of human excreta. Many diseases such as cholera, dysentery, gastro-enteritis and worm infections are transmitted from one person to another through the contamination of food, water and ground by excreta. This is largely due to unsatisfactory methods of excreta disposal.

For a prosperous city with ample water supply a water-carried sewerage system discharging to a sewage treatment plant or to the sea can satisfy all the requirements for safe and nuisance-free excreta disposal. However Figure 1 shows that sewers are only available to a small proportion of the urban population in developing countries, and the number of people without sewers is increasing, because population growth exceeds the provision of new sewer connections.

In low-density high-class residential areas throughout the world septic tanks are the most common means of providing water-carried sanitation where there is no municipal sewerage system. For the household a flush WC connected to a well-designed septic tank with an effective effluent disposal system has virtually all the advantages of a sewer connection.

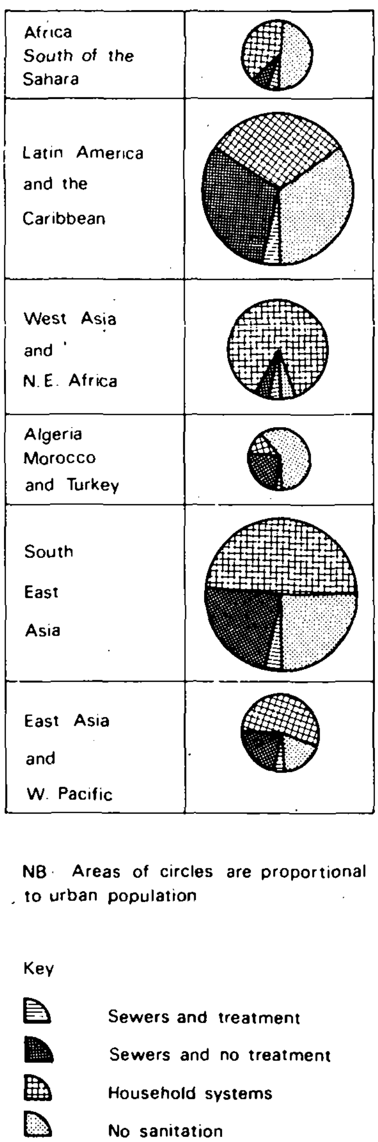


Figure 1 Urban sanitation in developing countries

The Septic Tank and the Aqua-Privy

In the 1860's John Louis Mouras built a masonry tank to receive the sewage from a small house in Vesoul, France. Twelve years later the tank was opened and found to contain little solid matter. Mouras patented the septic tank in 1881 and it was soon introduced in the United States and the UK. In the 1950's and 1960's hundreds of thousands of septic tanks were built in the United States and by 1970 it was estimated that more than 32 million people used septic tanks at their homes throughout the year—and many others used them at holiday homes.

In a septic tank system excreta are transported through pipes from water closets and are retained and partially treated in the tank. Sullage (used water from bathing, clothes washing and kitchens) may also pass to septic tanks, but in developing countries it is often discharged directly to the stormwater or monsoon drainage system, to separate soakaways, or onto gardens or agricultural land.

Where water is scarce, for example if it is obtained from a public standpipe or a single household tap, a small septic tank can be provided under the latrine. Excreta fall directly into the tank, from a squatting plate or seat above it, without passing through a water seal. This system is known as the 'aqua-privy', and is depicted in Figure 2.

Individual household septic tanks and aqua-privies are not low-cost solutions to the problem of providing satisfactory excreta disposal. They are therefore not suitable for the poorest groups of people in developing countries. However, they may provide the most appropriate method in certain circumstances, particularly in low-density residential areas where economy is not the greatest priority.

Where communal latrines are socially acceptable and are kept clean, septic tanks and aqua-privies can provide a satisfactory form of sanitation. There are good examples in West Africa and India[10, 18]. The 'comfort stations' of Ibadan[9] are aqua-privies.

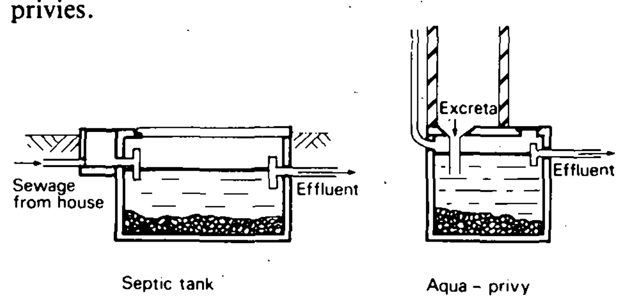


Figure 2 The septic tank and the aqua-privy

Design Objectives

The purpose of a septic tank or aqua-privy is to receive excreta and other wastes and to treat them to provide a satisfactory effluent for disposal into the ground or by other means. If the effluent is to pass into the ground the aim is to retain most of the solids in the tank so that there is minimum clogging of the ground around the soakage pit or drainage trench. If the effluent is to be discharged to surface water or irrigation the objective is to provide an effluent which has the minimum possible proportions of solids, of oxygen demanding material, and of micro-organisms which may transmit disease. The solids should be reduced as much as possible to lessen the problems of removal and disposal. Finally the septic tank or aqua-privy should cost as little as possible and should be easy to build and maintain.

In either a septic tank or an aqua-privy waste receives primary, or first-stage, treatment in the tank itself. Waste material enters the tank, solids separate out to form sludge and scum, and a partially-treated effluent is discharged. (Figure 3). The processes are complex and are described in Section 2.

The second stage of treatment is biological breakdown of the effluent which usually takes place as it soaks into soil from a soakpit or percolation trench. Alternatively, the effluent from a large septic tank (such as one serving an institution or a group of houses) may be treated in a percolating or trickling filter before discharge to a watercourse or irrigation area. Where the water table is high or where the septic tank or aqua-privy is built on impermeable clay or rock, a filter device of some kind may be incorporated in the tank itself. (Figure 4).

In a few places effluent from aqua-privies is passed through a low-flow sewerage system to waste stabilization ponds[15].

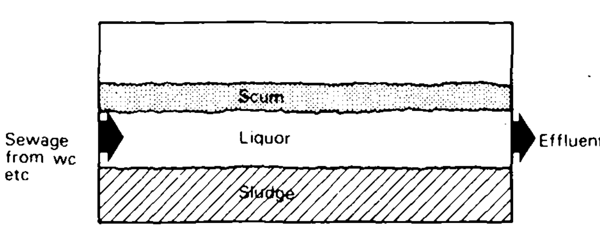


Figure 3 Separation of solids in a septic tank or aqua-privy

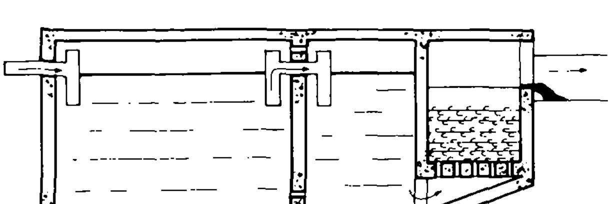


Figure 4 Septic tank with integral sand filter

2 FACTORS AFFECTING PERFORMANCE OF SEPTIC TANKS

The nature of sewage

Most of sewage is water. In a municipal sewerage system each litre of solid matter may be accompanied by two or three thousand litres of water. Similarly most of the flow from a wc to a septic tank is water for transporting solid excreta and for cleaning the wc bowl.

Quantity of sewage

The total amount of water used per person per day varies with the economic level of the community and the individual householder. It also depends on the availability of water—usually people in arid zones use less. Generally in developing countries the range is between 10–40 l/pd* for people obtaining their water from standpipes to 300 l/pd or more for those with full plumbing[19].

Aqua-privies function adequately with the addition of only a few litres per day—say 13–18 litres in all[20]. Some authors suggest a minimum such as 9 l/pd[7], but aqua-privies cause no trouble when the only added water is that used for anal cleaning—sometimes less than a litre for each defaecation.

Septic tanks dealing only with flow from wc's may receive 50 l/pd if each person flushes the pan each time it is used, whether for defaecation or urination. However, in developing countries where water is in short supply or the householder is charged on the metered quantity used, the pan may not be flushed every time the wc is used, and the flow may be 20 l/pd or less. If a septic tank deals with all the domestic wastewater this is likely to be about 90% of the water consumption, apart from that used for garden watering. In the absence of local information 120 l/pd is a reasonable figure[12] if there is a continuous supply of water.

Solids in sewage

Solids in septic tanks and aqua-privies are derived from excreta and anal cleaning material, and from bathing, laundry and kitchen wastes if these are discharged to the tank. The solids consist of both organic and inorganic matter, in solution or suspension, and also micro-organisms such as bacteria in large numbers. The organic matter includes carbohydrates and protein in faeces and food scraps. Inorganic matter includes salt and sand. The quantity of solid excreta (faeces) depends on diet. For example each day an adult with a 'european' diet based on fine white bread produces 115 grammes of faeces and an Indian labourer with a rice and vegetable diet produces 410 grammes of faeces[5].

For treatment in industrial countries the strength of sewage is often measured in 'Biochemical Oxygen

* l/pd = litres per person per day. This is sometimes referred to as 'litres per head per day' or 'litres per capita per day (lcd)'.

Demand' (BOD). This indicates the amount of oxygen required during aerobic* stabilization of organic matter. In developing countries the number of micro-organisms with faecal origin is usually more important. Billions of micro-organisms (viruses, bacteria, protozoa and helminths) are excreted by everyone each day. Most are harmless, but others are 'pathogens' which can cause disease.

Processes within the tank

Although a septic tank or aqua-privy is simply a box with no moving parts or added chemicals, the processes undergone by sewage in the tank are complex, and interact with each other.

The most important of these processes are as follows:—

Separation of suspended solids In still water heavy solids settle to form sludge. Material which obviously acts in this way includes sand, stones and ash, commonly used for scouring cooking utensils. Grease, oils and other light materials rise to the surface to form a floating scum, a process which is called flotation. A layer of liquor, sometimes called the supernatent, is left between the scum and sludge. Very fine particles (colloids) initially stay in suspension, but join together (coagulate) to form larger particles which fall or rise depending on their density. Coagulation is assisted by gases and particles of digested sludge rising through the liquid. Separation becomes easier as temperature rises, but the most important factor is the speed at which the liquor moves through the tank, and this depends on the retention time, as shown in Figure 5.

*'aerobic' means 'in the presence of or requiring air'. The opposite is 'anaerobic' where no air is involved.

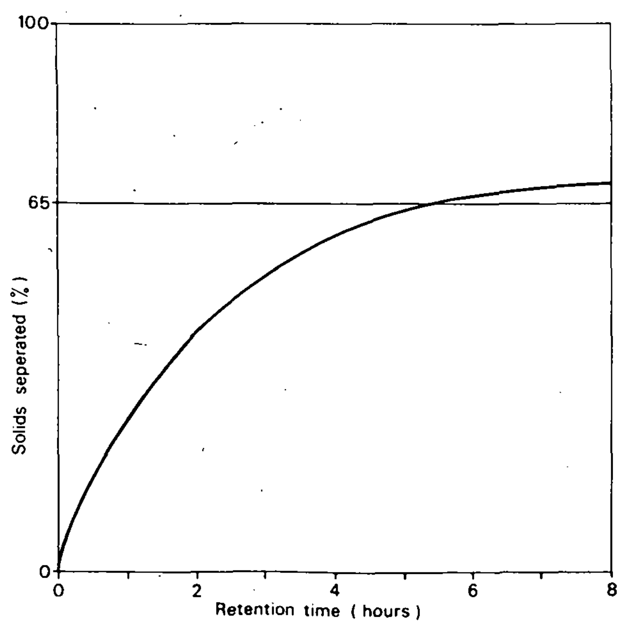


Figure 5 Typical relationship between solids separation and time of retention of sewage in tank

Digestion of sludge and scum Organic matter in the sludge, and to a lesser extent in the scum as well, is broken down by anaerobic bacteria. At first acids are formed and eventually most of the organic material is converted to water, carbon dioxide and methane. The gases rise through the liquor, taking small particles of partially-digested sludge with them. Digestion is accelerated by an increase of temperature up to about 35°C, and so takes place more rapidly in the tropics than in temperate zones.

Consolidation of sludge Due to the weight of liquor and top layers of sludge, sludge at the bottom of the tank is compacted, becoming denser and drier.

Stabilization of liquor During its retention in the tank, organic material remaining in the liquor is acted on by anaerobic bacteria, which break down complex substances to simpler ones. At first simple hydrocarbons like sugar and starch are reduced to water and carbon dioxide. Ammonia and other compounds containing nitrogen are broken down slowly.

Mixing The flow into a septic tank or aqua-privy usually comes in surges, as when a wc is flushed or the plug is taken out of a sink waste-pipe. These surges disturb the whole of the liquor, especially in small tanks. In a septic tank, these surges can be reduced by using a longer inlet drain pipe. In addition the temperature of the incoming sewage may be different from the liquor in the tank, further disturbing the liquor. Yet another cause of mixing is the rising gases and small particles from the sludge. In general these disturbances reduce the efficiency of separation.

Growth of micro-organisms Many kinds of micro-organisms grow, reproduce and die in the tank. Most are 'tied' to organic matter and so separate out with the solids. Some, accustomed to living in the human intestine, suffer in the hostile environment of the tank. Some are themselves heavy and sink to the sludge layer. There is an overall reduction in the number of micro-organisms, but generally viruses, bacteria, protozoa and helminths are present in large numbers in the effluent, the sludge and the scum.

Check list of factors affecting performance, and so affecting design of tank

Quantity of sewage:	whether water supply is from house connection or standpipe, whether continuous or intermittent delivery of water, number of people served by tank, whether sullage is passed to tank.

Solids in sewage:	diet of users, material used for anal cleaning, type of sullage, if included.
Processes in tank:	retention time of liquor, frequency of removal of sludge and scum, temperature—average and minimum, surges.

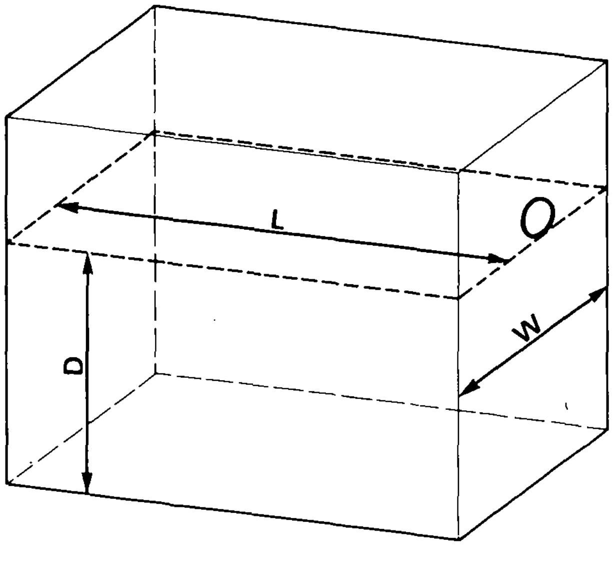
3 PRINCIPLES OF TANK SIZING

The purposes of tanks are firstly to produce a 'good' effluent, and secondly to retain sludge and scum so that the volume is reduced by digestion and consolidation and therefore the interval between successive emptyings is as long as possible. For both these purposes the tank capacity should be large. However, the larger a tank is the more it costs and the more space it occupies. Therefore a compromise is necessary.

Various formulae, codes and standards relate the capacity of the tank to the number of users and other factors. The capacity is the volume of liquor, sludge and scum up to the top liquor level (the invert of the outlet pipe). In certain circumstances the scum may rise above this level.

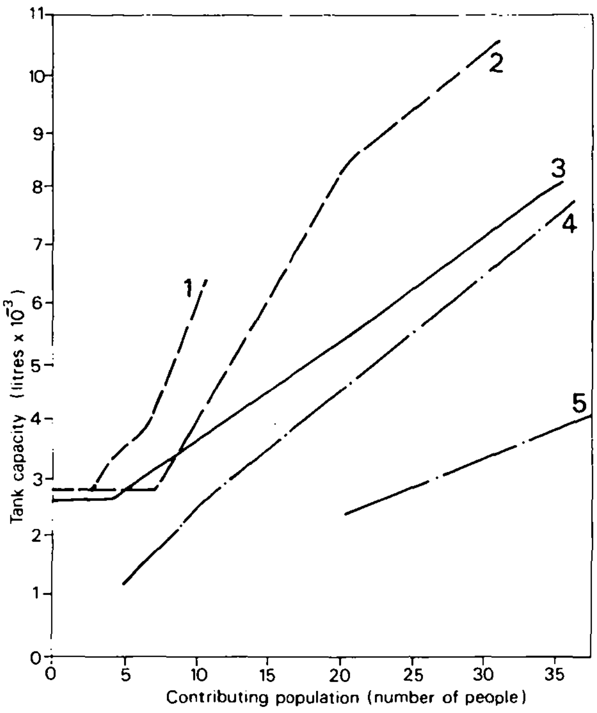
The simplest rules specify a single size for a family tank. For example in central Africa the capacity of a septic tank treating only wc waste was laid down as 1.2 cubic metres(13). A general rule for a family aqua-privy is that the capacity should be 1 cubic metre.

Figure 7 shows the relationships between capacity and the number of people served, for some widely-used standards. It can be seen that there is great variety. The formula used in the British Standard Code of Practice(1) gives the capacity in litres, C, as $C = 180P + 2000$, where P is the contributing population. In the US Manual(14) the capacity of household tanks is related to the number of bedrooms, and that of institutional tanks to the sewage flow rate. The Indian system(4) allows for the rate of sewage flow, the rate of sludge accumulation, the frequency of sludge removal and the effect of surge due to simultaneous discharge from sanitary fixtures.



C = LWD

Figure 6 Dimensions for tank capacity



Key

1 US Manual of Septic Tank Practice – private house assuming 1½ persons per bedroom

2 US Manual of Septic Tank Practice – institutional tank, single family dwellings, flow 75 gal/pd

3 British Standard Code of Practice CP 302:1972

4 Indian Standard Code of Practice for design and construction of septic tanks – 2 year cleaning interval

5 Indian Standard Code of Practice for design and construction of septic tanks – 6 months cleaning interval

Figure 7 Minimum recommended tank capacities

Many forms in current use reduce to the following general equation:

$C = A + P(rq + nS)$ litres, where
A is a constant;
P is the number of persons contributing to the tank;
r is the minimum retention time (in days) for sewage in the tank, just before desludging is carried out;
q is the sewage flow in litres per person per day;
n is the number of years between desludging;
S is the rate of sludge accumulation in litres per person per year.

In the British Code of Practice(1) A is given as 2000 litres and the term $(rq + nS)$ is 180 litres.

The retention time, r, is often taken as one day, but Fair and Geyer[3] quoted a formula which, converted to SI units is $r = (1.5-0.3 \log Pq)$ days. For a family of six people, discharging 120 l/pd, r thus becomes 0.6 days but for three people, r is 0.9 days.

The sludge accumulation rate, S, is taken as 77 l/pa* in the Indian Code.

Measurements in the United States[17] on 205 septic tanks gave the average rate of accumulation shown in Figure 8 and this rate is also used in the South African guide[6]. Measurements of sludge in eastern Nigeria showed that the rate of accumulation varied between 30 and 60 l/pa, with an average of 43 l/pa[2]. It is sometimes assumed that the rate of sludge accumulation is 40 l/pa when water is used for anal cleaning, and 60 l/pa when other material is used.

A simple method of calculating tank capacity is to assume that sludge and scum are removed when they occupy two-thirds of the capacity, and that the liquor retention time is never less than a day. The required capacity is therefore three times the total daily sewage flow, multiplied by the retention time, or $C = 3\ Prq$.

Another simple method is to allow a minimum depth of 300 mm (or some other arbitrary measurement) between sludge and scum, and allow for sufficient area to give one-day liquor retention. A further alternative is to calculate the capacity so that tanker lorries of the type used locally can take away all (or five-sixths) of the accumulated sludge as one or more full loads.

* l/pa = litres per person per annum.

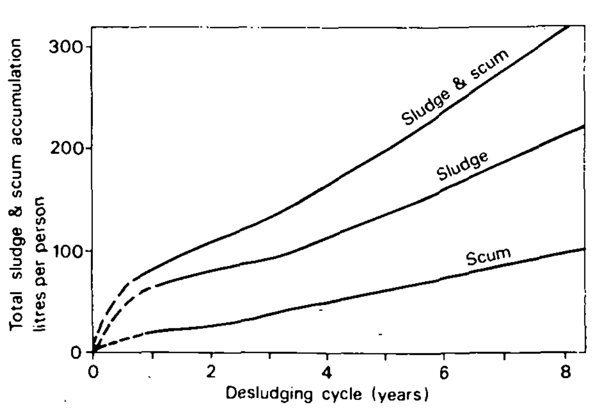


Figure 8 Rate of accumulation of sludge and scum in 205 septic tanks in U.S.A.

4 DETAILED METHODS OF TANK SIZING

So many methods and so many factors affecting the capacity are a reflection of the complexity of the processes in the tank. If a single project is to cover a large number of septic tanks or aqua-privies it may be worth-while calling in an expert for advice. Otherwise the following method of calculating the required size allows for local variations.

The tank has to accommodate both solids (sludge and scum) and liquids, and so there are three stages to the calculation:—

a. Calculate the capacity needed for sludge and scum storage

$A = Pnfs$ litres

where

A is the required sludge storage capacity

P is the number of people expected to contribute to the tank

n is the number of years between desludging. It should be assumed as 3 years if no other information is available.

f is a factor which is related to the ambient temperature. The digestion process occurs less readily at lower temperatures and so the effective capacity for sludge storage has to be increased. The appropriate value for 'f' can be read from Table 1.

S is the rate of sludge and scum accumulation (in litres per year) and depends upon the materials used for anal cleaning as well as upon the volume of waste water received by the tank. Appropriate values are given in Table 2.

Table 1 Values of sizing factor 'f' for stated desludging intervals and temperatures

Number of years between de-sludging	Ambient temperature		
	More than 20°C throughout year	More than 10°C throughout year	Less than 10°C during winter time
1	1.3	1.5	2.5
2	1.0	1.15	1.5
3	1.0	1.0	1.27
4	1.0	1.0	1.15
5	1.0	1.0	1.06
6 or more	1.0	1.0	1.0

Table 2 Rate of sludge accumulation 'S' in litres

Material used for anal cleaning	Water closet or latrine wastes only	Household sullage in addition to waste
Water, soft paper	25	40
leaves, hard paper	40	55
sand, stone, earth	55	70

b. Calculate the capacity needed for liquor retention

B = P q litres

where

B is the required liquor retention capacity

q is the sewage flow in l/pd

If no local information is available for q, the following values should be assumed:

120 l/pd if water is continuously available at good pressure and the house has several sanitary fittings (wc, bath or shower, sink, etc), all of which are connected to the water supply and the septic tank.

50 l/pd if water is continuously available at good pressure, but only to a compound tap, and domestic wastewater goes to the tank.

40 l/pd if water is continuously available at good pressure, and the wc alone is connected to the water supply and the septic tank.
(If water is not available all the time, or pressure is sometimes low, multiply the given value by the proportion of the day during which it is normally available).

20 l/pd if water is obtained from a nearby standpipe and domestic wastewater is discharged to an aqua-privy tank.

5 l/pd if water is obtained from a public standpipe or other source and only the minimum water is used to clean the latrine and top up the aqua-privy tank.

If it is certain that the water supply will improve during the next few years, the value of q should be based on the expected water supply.

c. Calculate the total capacity and shape of the tank

Having made the separate calculations of the capacities needed for storage of solids and liquor, the total capacity required is simply the sum of the two:

ie C = A + B

unless B is less than half of A, in which case the minimum size should be

C = 1.5A

In this way the *minimum* capacity for proper functioning of the tank can be found. However, for small tanks the size is often determined by other considerations. For example, the width of the tank should not be less than 600 mm if a man is to work inside, either to build the tank or to empty it. Another limitation is the need to provide enough surface in an aqua-privy for both the squatting slab and a removable cover for desludging. Again, it may be as cheap to build a slightly larger tank using whole blocks. There is no technical disadvantage in making a tank which is bigger than the minimum capacity.

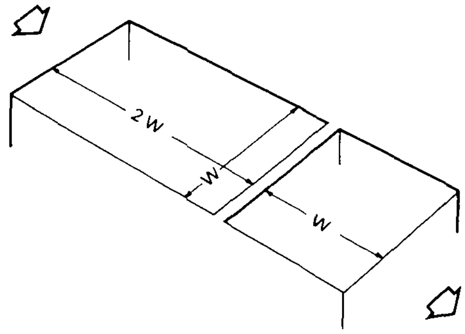


Figure 9 Recommended proportions for a two-compartment septic tank

The actual size may also be modified by considerations of the shape and compartmentalisation of the tank. Septic tanks are usually rectangular in plan, although other shapes can be used. Dividing the tank into two compartments produces a better effluent, as most of the sludge is deposited in the first chamber. This first compartment may be two thirds of the total tank capacity, and so for small tanks the first chamber may be twice as long as it is wide, and the second compartment may be square in plan, as sketched in Figure 9.

The depth of the liquid in small aqua-privies may be less than a metre, but for septic tanks the depth should never be less than 1.2 metres, and a minimum of 1.5 metres is usual. The soffit of the cover slab should be at least 300 mm above the water level. The floor of the tank is usually flat, although the floor of the first compartment is sometimes sloped towards the inlet end, where sludge is removed.

Flow of liquor from the first compartment to the second is best through horizontal slots. It is essential that these are below the scum level and above that of the sludge. Recommended dimensions of the slots for a 1.5 metre deep tank are two or more slots 75–100 mm deep with their tops 225–300 mm below the water level.

5 EXAMPLES OF TANK SIZING CALCULATIONS

The following examples indicate how the recommendations in Section 4 can be applied for a family of six persons, ie P = 6 throughout.

Example i. Aqua-privy: equatorial climate: water obtained from standpipe some distance away: leaves and grass used for anal cleaning: no sullage to tank: sludge removal every three years.

First stage of calculation:—

A = PnfS

Temperature more than 20°C throughout year, n = 3, so f = 1.0

Leaves and grass used for anal cleaning, no sullage, so S = 40 l/a

Therefore A = 6x3x40 = 720 litres

Second stage:—
B = Pq
Minimum water used, so q = 5 l/pd
B = 6x5 = 30 litres

Total capacity:—
B is less than half A, so C = 1.5A = 1.5x720 = 1080 litres
1080 litres = 1.08 cubic metres
With a minimum depth of 1 metre, the plan area of the tank is 1.08 square metres. With two compartments, a suitable size would be as shown in Figure 10.

Example ii. Septic tank: climate cold in winter: house with full plumbing: continuous water supply: all wastewater to tank: sludge removal every three years.

First stage:—
A = PnfS
Temperature less than 10°C in winter, n = 3, so f = 1.27
Soft paper used for anal cleaning, sullage to tank, so S = 40 l/pa
Therefore A = 6x3x1.27x40 = 912 litres

Second stage:—
B = Pq
Full water connections, so q = 120 l/pd
B = 6x120 = 720 litres

Total capacity:—
B is more than half A, so
C = A + B = 912 + 720 = 1632 litres
1632 litres = 1.632 cubic metres
With a depth of 1.5 metres, the plan area of the tank is 1.088 cubic metres. With two compartments, the areal dimensions of Figure 10 would again be suitable, although a greater depth is required.

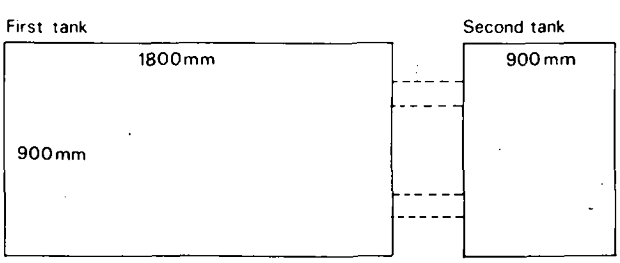


Figure 10 Plan and dimensions, examples (i) and (ii)

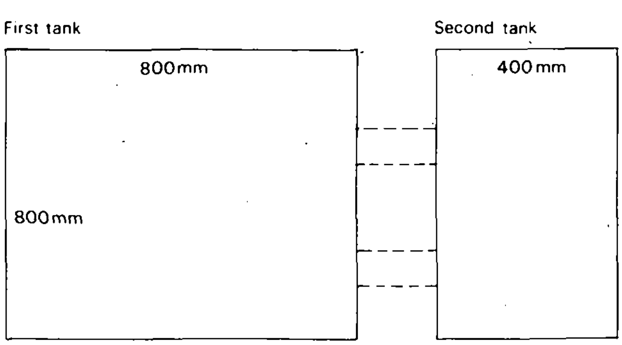


Figure 11 Plan and dimensions, example (iii)

Example iii. Septic tank: temperature during year 15°C–30°C: house with full plumbing and luxurious use of water: all wastewater to tank: sludge removal every ten years.

First stage:—
A = PnfS
Temperature more than 10°C throughout the year, n = 10, so f = 1.0
Soft paper for anal cleaning, sullage to tank, so S = 40 l/pa
Therefore A = 6x10x40 = 2400 litres

Second stage:—
B = Pq
Luxurious use of water, so q = 200 l/pd (even more than indicated on page 6)
B = 6x200 = 1200 litres

Total capacity:—
B is equal to half A, so C = A + B = 3600 litres
3600 litres = 3.6 cubic metres
With a depth of 1.5 metres, the plan area is 2.4 square metres
With two compartments, a suitable size would be as shown in Figure 11

6 MATERIALS, CONSTRUCTION, AND MAINTENANCE

General construction

The most common form of construction in developing countries is a concrete floor, rendered blockwork walls and a reinforced concrete cover slab. The floor is usually 100 mm thick unreinforced concrete, but some reinforcement may be provided in poor ground. The walls of a small tank can be made with 150–200 mm blocks, rendered with good cement mortar on the inside to make them completely watertight.

Prefabricated septic tanks are available. Some are made with asbestos cement and an expensive but easy-to-install tank made of glass-reinforced plastic is exported from the UK in sections so that it can be stacked for shipping (see Figure 12).

Septic tanks have also been made using concrete pipe sections, two or three in series[8]. However, some engineers have been disappointed when using readily-available locally-manufactured pipes, because the work involved in fixing the inlet and outlet pipes outweighed the advantages of using the prefabricated pipes. Concrete pipes are sometimes used for household aqua-privies. Only one pipe (the outlet) has to be fitted through the wall[16].

Prefabricated aqua-privies are produced from a variety of materials. Concrete units were built in large numbers in the West Indies from about 1947[11]. The design shown in Figure 13 was used in Calcutta's slum upgrading projects in the late

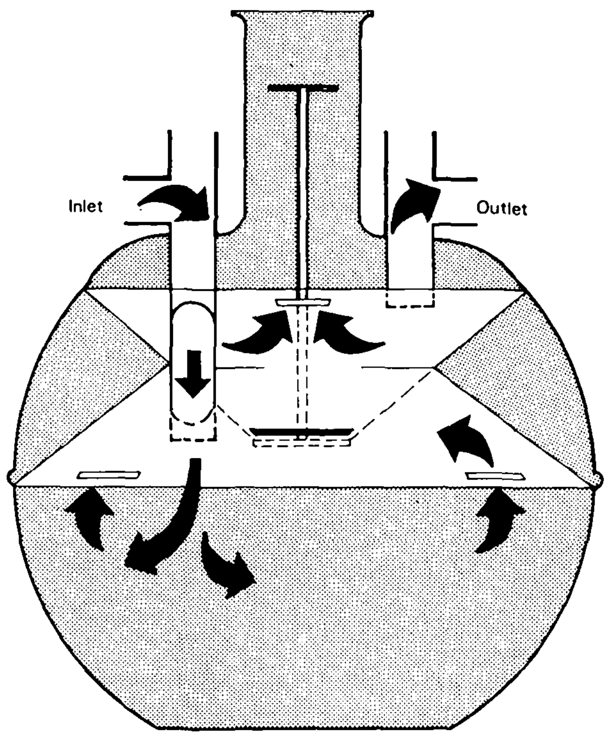


Figure 12 Typical proprietary septic tank, made from glass-fibre reinforced plastic

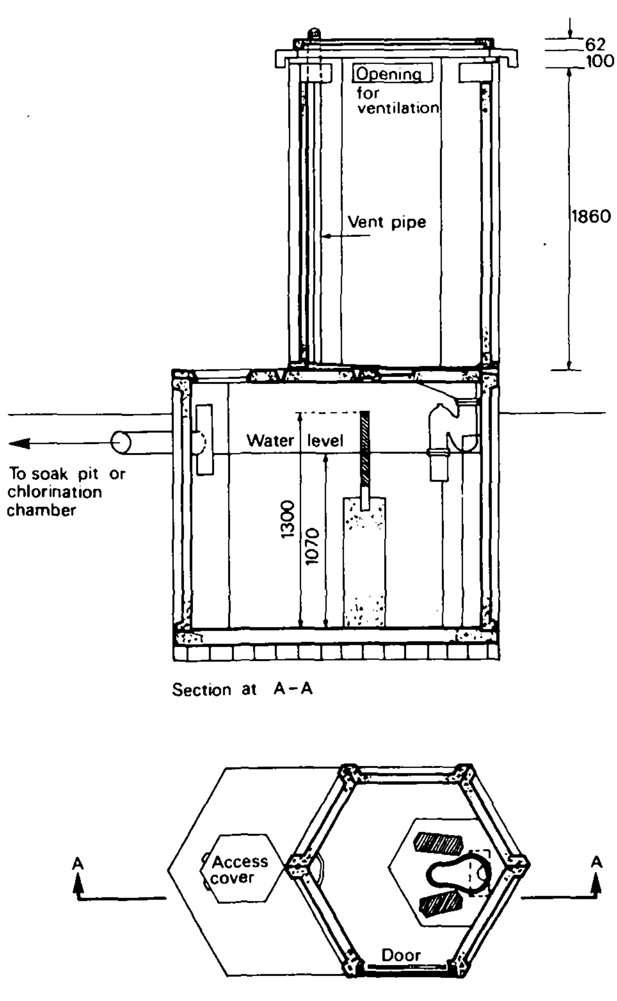


Figure 13 Aqua-privy for slum upgrading scheme in Calcutta

1970's[10]. However, like septic tanks, most aqua-privy chambers are built on site with concrete or sandcrete blocks rendered on the inside. This has the advantage of providing employment for local builders.

Inlets to septic tanks

Perhaps the most critical aspect of septic tank construction is the arrangement of inlets and outlets. They should introduce sewage to the tank and remove the effluent with the least disturbance of settled sludge and scum. In order to limit the action of surge flows from flushing wcs and unplugged baths and sinks, the pipe to the septic tank should not be less than 100 mm diameter, and the gradient not steeper than 1.5% (1 in 66) for the last 10 metres. For tanks less than 1.2 metres wide the most common inlet device is a T-junction such as in Figure 14, as it permits blockages to be cleared by 'rodding'. The junction diameter should not be less than that of the inlet pipe; the top limb should rise at least 150 mm above the water level, and the bottom limb should extend about 450 mm below the water level.

For larger tanks the inlet may be provided by twin bends (Figure 15) or a submerged slot extending the full width of the tank. This is not usually necessary for septic tanks serving a single household.

An inspection chamber is often built just outside the tank. This is used to clear any blockage in the pipe leading to the tank, and so is not really part of the tank.

Aqua-privy chutes

Most aqua-privies are built under a squatting slab and a chute is formed by a vertical pipe. This is often 100 mm internal diameter. It is essential that the pipe extends at least 75 mm below the liquor level in the tank. The pipe may be integrally cast with the squatting plate.

There are two main variations to the usual chute;

a. Aqua-privies with seats are built where the local practice is to sit rather than squat, as in the West Indies and Botswana. (Figure 16).

b. Pour-flush water seals can be provided where the local practice is to use water for anal cleaning, as in the Calcutta type shown in Figure 13.

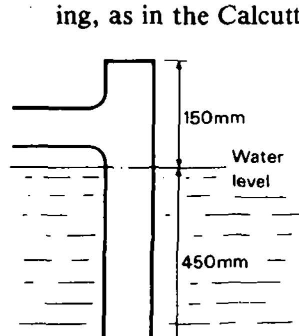


Figure 14 Simple inlet to septic tank

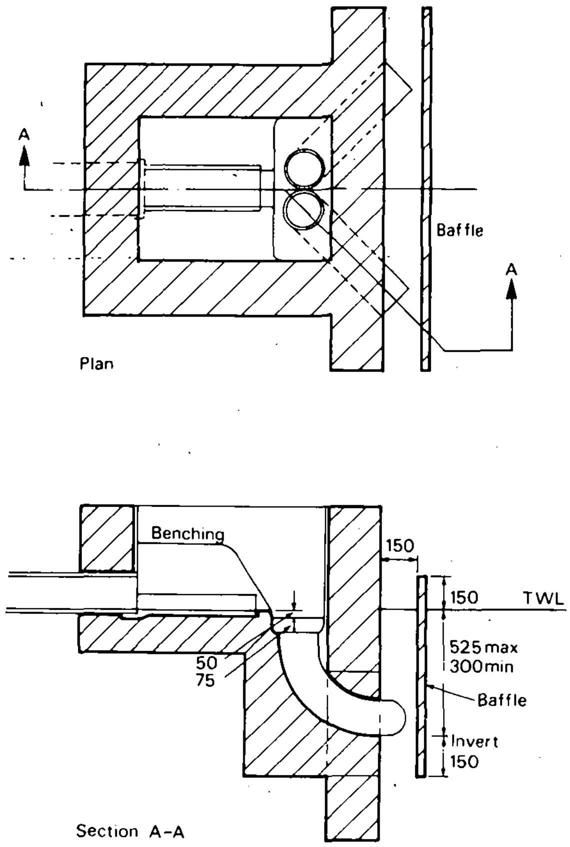


Figure 15 Twin inlet to large septic tank

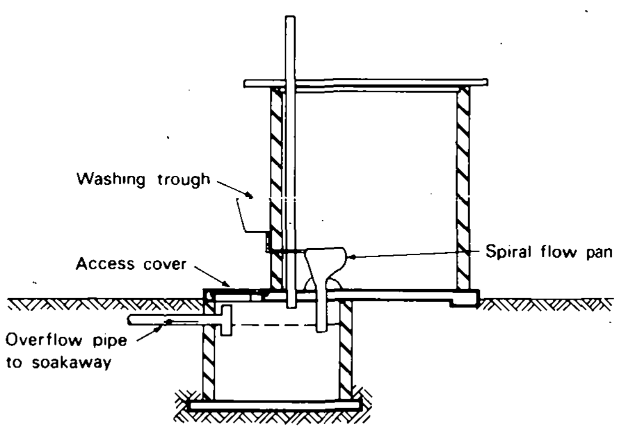


Figure 16 The type B aqua-privy used in Botswana

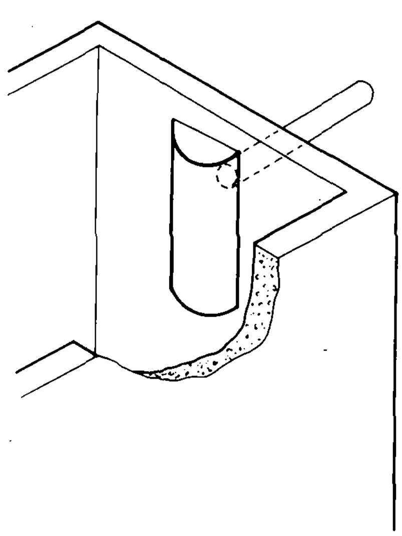
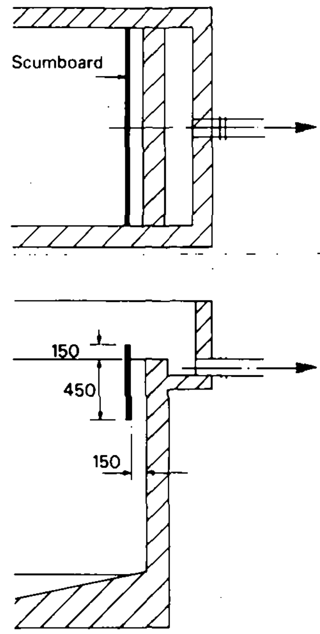


Figure 17 Simple outlet from septic tank



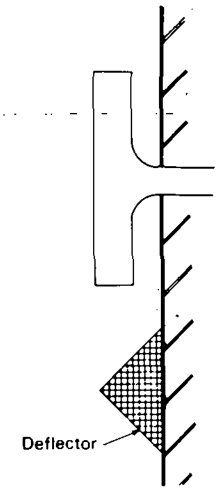


Figure 18 (left) Weir outlet from large tank and
Figure 19 (right) Deflector at septic tank outlet

Outlets

Outlets for septic tanks and aqua-privies less than 1200 mm wide are usually made with a T-junction set so that the bottom of the horizontal leg is 50–75 mm below the level of the inlet pipe. The bottom of the pipe is called the invert, and the outlet invert fixes the water level in the tank. As with the inlet T-junction, the vertical leg must extend above the top and bottom of the scum layer. Liquor must be discharged from the liquor zone between the scum and the sludge. An alternative to the T-junction is a guard plate made of zinc, ferrocement or asbestos cement, as shown in Figure 17.

For tanks wider than about 1200 mm the outlet is best formed by a weir extending right across the tank, with a baffle about 150 mm away, as in Figure 18.

An alternative, used where a filter is incorporated into the tank, is to have two or more T-junctions spread across the outlet end of the tank.

With small tanks, surge into the tank results in increased outflow, although the surge is attenuated (drawn out in time, but not so severe) by passage through the tank. With rapid discharge there is danger that the upward movement of liquor will drag sludge with it. To prevent rising sludge passing through the outlet pipe a deflector can be provided (Figure 19).

Ventilation

Digestion of the sludge, and to a lesser extent the scum, results in the release of gases. These are mostly carbon dioxide and methane, but there are small amounts of other foul-smelling gases and some form of ventilation is therefore necessary for the tank. In household systems a screened outlet is often placed at the upper end of the drains and gases escape from the tank through the upper limb of the inlet T-junction. An alternative is to allow gases to escape through holes in the access covers. This does not avoid nuisance from bad smells, but prevents a build-up of pressure in the tank. A better method is to provide a ventilating pipe for the tank itself, and this is suitable both for aqua-privies and for septic tanks.

Operation and starting-up

A newly-built septic tank or aqua-privy should be tested for water-tightness by filling it with water and allowing the water to stand for a day. The water need not be piped drinking water if there is a stream, well or irrigation canal nearby. After testing, the tank should be left full of water. Digestion is helped by throwing in some well-digested material (such as sludge from an old tank).

Maintenance

The only maintenance necessary for well-constructed and properly-used septic tanks and aqua-privies is the removal of surplus sludge and scum to leave a clear central zone for liquor. Proper use of an aqua-privy involves keeping the squatting plate clean and ensuring that the water level in the tank does not fall by adding enough water to make up for evaporation. If the chute becomes blocked it may be necessary to clear it with a stick.

Regular inspection of the tank is necessary to find out whether the sludge and scum levels are acceptable. A septic tank should be inspected at half the design time. If hard material is used for anal cleaning the sludge level in a small aqua-privy should be checked at monthly intervals.

The most satisfactory method of sludge removal is to use a tanker lorry equipped with a pump and flexible suction hose. Removable covers should be provided for all compartments of septic tanks, and are best at the inlet ends, where sludge accumulation is greatest. It is not uncommon for the suction pipe to be lowered down the chute of an aqua-privy, but this often results in damage to the chute. Therefore a removable access cover should be built in the top or side of the tank.

The bottom of the sludge is well-consolidated and a high proportion of the material may be sand cemented together by fine particles. Most of this material should be removed. Some tanker lorries are equipped with a hosepipe so that a jet of water can stir up the hard deposits. If a jet is not available the sludge should be disturbed with the end of the suction pipe or with a stick or long-handled spade.

When a tanker lorry is not available, it is usual to dig out the sludge with a long-handled shovel, and to remove it in buckets or tins. This is unpleasant work and can be a health hazard, as the sludge may still contain some pathogenic micro-organisms. An alternative used in some places is an animal-drawn tank fitted with a hand-operated suction pipe.

By whatever means it is collected, the material removed from the tank is a mixture of harmless matter (such as sand and well digested sludge) and potentially harmful fresh sewage and undigested sludge. It can only safely be used for agriculture or horticulture when persistent pathogens have been eliminated—for example by a long period of drying or by composting with vegetable waste. The provision of a sound collection and disposal service is essential for the health of the community.

A septic tank should never be completely emptied. Some old sludge should always be left at the bottom to ensure that digestion continues. (This is known as 'seeding'). After desludging, the tank should be filled with water. It is particularly important to fill the tank of an aqua-privy so that the bottom of the inlet is covered.

7 CONCLUDING REMARKS

Septic tanks and aqua-privies can provide acceptable methods of sanitation for low density housing schemes in many developing countries. In order to reduce their construction costs, the tanks should be as small as is consistent with efficient operation, and this note has given some details of how the required size can be determined for particular circumstances.

Various assumptions have been made in the text (eg on the rate of sludge build-up) but accurate sizing procedures require a knowledge of several aspects of the use and performance of septic tanks and aqua-privies. This information is not readily available, partly because tanks are usually under the ground, on the private land of the householder, and so may be forgotten about or ignored for many years.

Very little information has been published about performance of these systems, even in the USA or UK, and even less has been written about installations in developing countries.

The author would appreciate receiving from readers any information which would help with the design and sizing process. The type of data needed are the rates at which sludge and scum accumulate in tanks, related to the number of users and to the material which the tanks receive. Information should be sent to the author at Loughborough University, or to the Overseas Division of BRE, at the address given inside the front cover of this note.

8 FURTHER READING

The references marked* give details of septic tanks and aqua-privies in developing countries.

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OTHER PUBLICATIONS

The following publications are also available from the Overseas Division of Building Research Establishment. Many of them are free of charge, but where a price is indicated this relates to the price in UK. Special prices, which include packing and postal charges, may apply to copies sold to the developing countries, and intending purchasers are invited to write for details to the address shown on the inside front cover.

Roofs for warm climates R Sperling
Deals with the requirements of flat roofs in modern tropical buildings. Should assist architects and builders to improve the general standard of roof construction in warm climates.
138 pp 1971 £1.25

Small buildings in earthquake areas A Daldy
This handbook is for builders and others who construct small buildings in earthquake areas. In this context a 'small building' means one of less than three storeys, with a total floor area of less than 120 sq m. By following the construction methods outlined in this guide, many lives could be saved in future earthquakes.
40 pp 1972 £0.75

Third world urban housing Shankland Cox Partnership
A guide for everyone concerned with housing problems in developing countries. The report covers the whole range from devising a housing strategy to planning and implementing projects on the ground and is extensively illustrated with examples of housing schemes in different countries.
250 pp 1978 £5.40

Accommodation standards for educational building
M Simmonds
A guide for educational authorities and architects concerned with formulating standards and with school building programmes in developing countries. It summarises the standards of the United Kingdom's Department of Education and Science, and includes those of other authorities for comparison.
110 pp 1977 (revised) unpriced

Limiting the temperature in naturally ventilated buildings in warm climates
P Petherbridge CP 7/74
Describes a method for calculating indoor temperatures, which is then used to analyse the influence of U-value, solar absorptivity, thermal storage etc on limiting these temperatures. Provides tentative climatological data for humid and arid West African climates.
22 pp 1974 unpriced

Data for the design of thermal and visual environments in buildings in warm climates
P Petherbridge CP 8/74
Design of these environments in buildings requires data on climatological parameters, especially sun and sky radiation. Radiation intensities for temperate and for warm climates are discussed. Incorporation of a simplification of the clear sky illuminance distribution into a daylight design aid is proposed.
15 pp 1974 unpriced

An analysis of some observations of thermal comfort in Roorkee, India and Baghdad, Iraq
J Nicol CP 4/75
Data of air movement and temperature, and assessments of thermal sensation and skin moisture of 16 subjects during hot dry weather are analysed to give indices for thermal comfort in relevant climates.
11 pp 1975 unpriced

The Middle East—an outline of the geology and soil conditions in relation to construction problems
P Evans CP 13/78
The paper briefly summarises information collated from geological maps, journals and reports of site investigations and aggregate surveys. It contains a brief geological description for each of the countries considered, and relates the geology and soil conditions to some of the construction problems which occur.
17 pp 1977 unpriced

Brickmaking in developing countries J P M Parry
A review of brickmaking technologies in nearly 40 developing countries, examining the range and economics of the various methods, and explaining the causes of common production defects.
88 pp 1979 £6.35

Tropical building studies
These studies were first published in 1960, and a few copies are now available free of charge to interested readers. The contents may be somewhat dated, but they are offered as an addition to the current range of publications. The titles available are:-
Densities in housing areas, P H Stevens ARIBA, AMTPI
55 pp 1960
Buildings for the storage of crops in warm climates, W H Ransom
24 pp 1960
Solar radiation: Thermal effects on building materials, W H Ransom
18 pp 1962

Tropical Building Legislation
A series of notes was published between 1960 and 1969, containing model regulations for building in tropical climates. Subjects included temporary housing areas, fire regulations, and a model main ordinance. Details are available from Overseas Division.

Other titles
Papers are in course of preparation on a number of subjects of interest to readers in developing countries. Details will be given in Overseas Building Notes as they are published.

OVERSEAS BUILDING NOTES—Titles Available

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187	August 1980	The design of septic tanks and aqua-privies (John Pickford)

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