3. It costs slightly more than ordinary pit privies, but less than aqua privies.

4. In many rural areas of the world, it would require a change in customary use of cleaning materials.

5. It is not readily applicable in areas with impermeable soils.

6. It cannot be used in freezing climates.

In countries of South-East Asia, latrines with water-seal slabs have been used for more than twenty-five years, and appear to have been readily accepted by the rural people of the region, as they fit in well with their customs and religious patterns. Experience shows, however, that the water-seal latrine should be used only in family installations, that it is not suitable for use in public conveniences.\(^{59}\)

**THE BORED-HOLE LATRINE**

**Description**

The bored-hole latrine is only a variation of the pit privy, from which it differs by the much smaller cross-sectional area of its pit. The latrine floor, or slab, and the superstructure are the same for both types of installation. The bored-hole latrine, which was developed 30 years ago in the Dutch East Indies,\(^{40}\) is now extensively used in countries of Africa, the Middle East, South-East Asia, the Western Pacific, and South America.

**Design and Function of Its Parts**

**The bored hole**

This consists of a circular hole usually 40 cm (16 in.) in diameter bored vertically into the ground by means of an earth auger, or borer, to a depth of 4-8 m (13-26 ft), most commonly 6 m (20 ft) (see Fig. 51 and 52). Holes of 30 cm (12 in.) and 35 cm (14 in.) have also been used extensively, and are easier to bore than is the larger, 40-cm (16-in.) size; but experience shows that their capacities are much too small. In fact, the volume of the 40-cm- (16-in.-) diameter hole is considerably smaller than that of the pit privy of same depth, the ratio being 1 to 6.5 in favour of a pit 90 cm (3 ft) square. The same pit privy, 90 cm (3 ft) square, is 11.5 times larger than a 30-cm- (12-in.-) diameter bored hole of the same depth.

Because of its small capacity, the bored-hole latrine dug into dry ground and used only by a family of 5 or 6 persons does not last more than 1½-2 years in most instances, and less where bulky cleansing materials
are used. The solution in such a case is to build two holes a short distance apart and to use one at a time. When the first hole is filled, it is covered with 50 cm (20 in.) of well-tamped earth, and the slab and superstructure are skidded over the other hole. After about one year, the well-digested material in the first hole is removed, making the hole available for the next move. The life of a bored hole (like that of the pit privy) is appreciably increased when it penetrates 1-2 m (3-6 ft) into ground water, for reasons already discussed under "life of a pit" (p. 43). Chiefly because of its small capacity, the bored-hole latrine is a family type of installation and cannot be used as a public convenience.

The greatest engineering difficulty encountered in the design and construction of bored-hole latrines is the collapse or caving of the pit walls. Caving is rather frequent with this type of latrine, especially in sandy or alluvial soils, and is sometimes so severe as to obstruct the hole completely. In some instances, holes have been bored into dry and firm ground requiring no casing and have caved in during the next rainy season when the ground water rose and flooded the pit. To avoid such occurrences, casings or linings should be provided to support the walls of the pits. Much care must be taken, when planning bored-hole latrine installations, to study ground formations and the fluctuations of ground-water levels in the area under consideration.

Because of the small dimensions of the bored hole, the upper section of the pit is likely to be soiled by both excreta and urine. This may result in offensive conditions, and flies may be attracted and breed in the earth below the squatting plate. To alleviate this situation, it is good practice to line the upper 30-60 cm (12-24 in.) of the bored hole with a tight, impervious lining (e.g., concrete, baked clay).
FIG. 52. BORED-HOLE LATRINE IN ALLUVIAL SOILS, SUITABLE FOR FLOOD PLAINS AND TIDAL AREAS

* Built in East Pakistan. Measurements shown are in centimetres.

A = Round slab with slope to centre, as shown in Fig. 27
B = Original ground
C = Bamboo lining required in mound
D = Bamboo lining full length if required
E = Tamped earth mound

The floor or slab

The floor of a bored-hole latrine is identical in size and shape to that of the pit privy (see p. 52). When the floor is built of concrete, it needs little or no reinforcement because of the small unsupported span (40 cm, or 16 in.) of the bored hole latrine slab. The thickness of the concrete
slab may be safely reduced to 5 cm (2 in.) on the slab edge and to 4 cm (1.5 in.) at the centre. It is desirable to use hog-wire or similar reinforcement, chiefly for the purpose of preventing cracks caused by temperature differences and by shocks during transportation. The floor is usually raised 15-20 cm (6-8 in.) above normal ground level, but a specially built base is generally not necessary.

The mound

A mound of earth should be built around the floor to protect it against run-off. The mound should be at least 50 cm (20 in.) wide and well tamped. In flood plains and tidal areas, the floor should be elevated above the highest water level, and the mound solidly built. As shown in Fig. 51, it may be built of moist earth, well-tamped in small layers of 15 cm (6 in.); but where necessary, the mound should be revetted with flat stones. As in the case of the pit privy (p. 65), it is preferable to supplement the earth mound in front of the entrance door with a masonry or brick step to help prevent dirt from being tracked into the privy on the user's feet.

The superstructure and the ventilation

The superstructure is identical to that recommended for pit privies (p. 65). While the house should be ventilated in order to minimize the odour nuisance, the ventilation of bored holes is generally considered to be unnecessary. It may be noted that, thus far, the bored-hole latrine has been used almost exclusively in the tropics, where temperature differences between the air in the pit and the outside air are slight; as a result, any draught of air through a vent pipe would be negligible.

Location of Bored-Hole Latrine

The basic considerations regarding the placement of latrines in general with respect to sources of water supply and dwellings have been previously discussed (see p. 32). In the case of the bored-hole latrine, the danger of pollution of the ground water is obvious since it is generally desirable that the bored hole penetrate it deeply for more efficient and durable operation. However, the rules governing the location of bored-hole latrines are the same as those for the pit privy.

Advantages and Disadvantages

The advantages and disadvantages of bored-hole latrines are in many respects similar to those of pit privies. Given proper construction and location, they satisfy most of the requirements set forth under "criteria for selection" (p. 39).
In particular, the bored-hole latrine is cheap and easy to construct in ordinary soils. In a WHO-aided rural sanitation project in East Pakistan, the cost of a bored-hole latrine in 1955 was found to be Rs. 11/15 (US $3.58), plus Rs. 6/- (US $1.80) for a woven bamboo lining. In Egypt, the estimated price in 1952 was US $5.60.

Penetration of the ground water may be either an advantage or a disadvantage, as previously noted. In addition, the formation of a thick scum above the water level in the hole may seriously impair the operation and life span of the latrine. In such situations, and especially in areas like the Nile delta in Egypt, where heavy fluctuations of the ground water bring the water table within a few feet of the ground level, the bore-hole fills up quickly since the solids deposited float over the scum. By breaking the scum layer with a pole (a procedure which is admittedly impractical in many instances), the efficiency of the latrine may be restored. However, recent investigations have shown that proper location is more important than a great distance between a latrine of any type, including the bored-hole latrine, and the source of water supply.

The bored-hole latrine has been classified among other less desirable types of excreta disposal installations for the following reasons:

1. It requires special equipment for its construction.

2. If it does not penetrate ground water over approximately one-third of its depth, its life span is extremely short (see discussion on "life of a pit", p. 43), a most serious consideration in the success or failure of an excreta disposal programme.

3. In many countries it is difficult to secure cheap but strong and durable materials for supporting the walls of the bored hole against caving.

**Construction**

**Materials**

For the construction of linings, or casings, the following materials are most commonly used: wooden strips, bamboo, split cane, and baked clay. In addition, it is often possible to find in rural areas some kind of material which may be woven or made by the rural artisans themselves for use in the construction of casings. In large areas of Asia, bamboo is plentiful and used for this purpose. It has the great advantage of lasting for years under water without a preservative (although tar is used in Indonesia for this purpose). However, untaimed bamboo and other wooden linings in dry pits or above the water line in wet pits are sometimes attacked by insects, although it is possible that they may last as long as the latrine itself (in the case of dry pits, at least). In areas where pottery is made,
cheap linings can be manufactured for bored-hole latrines in the form of perforated clay pipes. In the Americas, split cane has been used with success in the same manner as bamboo.

Whatever the material used, it must be remembered that the purpose of a lining is only to prevent caving. The perforations, or holes, in the lining should be as large as the soil permits, in order to allow for prompt leaching of liquid waste and dissolved solids out of the pit into the ground. In areas where the ground-water level is high, or which are subject to flooding, the latrine floor is elevated above the surrounding ground in the manner shown in Fig. 52. In such a case, the portion of the lining which passes through the elevated mound and penetrates the first 50 cm (20 in.) below the normal ground level should preferably be impervious and built of strong material, such as concrete.

**Boring the hole**

*Equipment*

One 40-cm (16-in.) earth auger, one auger shaft, one handle, one tripod, one pulley block, and one auger guide.

There are many types of auger which can be purchased on the market for different purposes. Fig. 53 and 54 show various types of auger and equipment which are suitable for bored-hole construction. A good latrine-boring auger for ordinary soils (not containing boulders, rock, or hardpan) might fulfil the following specifications:

Double-bladed, hand-operated earth auger, with a nominal diameter of 40 cm (16 in.), capable of boring through moderately difficult soils to a depth of 6 m (20 ft). The blades to be high carbon steel, 5 mm (7/16 in.) thick, with the points strapped to prevent the blades from springing apart. The yoke and plug to be malleable iron cast as one piece, the plug having an external diameter of 37.5 mm (11/2 in.) to fit into a standard 11/2 in. diameter iron pipe.\(^a\) The plug to be cast with holes, each 10 mm (5/8 in.) in diameter through the body of the plug at right angles to its axis, with bolts to fit. In use, the operating shaft, consisting of standard 11/2-in. iron pipe, fits over the plug and is secured by the bolts through corresponding holes in the pipe shaft. The auger to be furnished completely assembled, pipe shaft excluded.

An additional remark which may be made about double-bladed auger design is that the edges of the blades should not be so far apart as to leave large open spaces through which settling sand and soft mud may fall out when the auger is being raised. Earth augers of the disc, helical, or worm types may be used in boring through clay and softer soils without stones.

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\(^a\) In many countries where the metric system of measurement is used, this would be replaced by a 40-mm-diameter pipe, and the other specifications would be altered accordingly.
The auger shaft may be either round or square to fit the yoke of the auger selected. To fit the auger for which the above specifications are given, ordinary 1½-in.-diameter iron pipe will be used. This equipment will include: (a) one length, 6.70 m (22 ft), of standard 1½-in. iron pipe perforated across its barrel every 60 cm (2 ft) with 10-mm (3/8-in.) holes; (b) one 10-mm (3/8-in.) bolt or steel pin 9 cm (3½ in.) long; (c) one coupler (which may be required) for connecting two separate lengths of 1½-in. pipe, preferably an inside or plug-type coupler, with holes 10 mm (3/8 in.) in diameter, at right angles to the axis of the coupler, with bolts to fit.

The handle will include a pipe cross, 50×30 mm (2×1 1/4 in.) fitted to slide along the 1½-in. round shaft, tapped to take two handle branches, each consisting of a standard 30-mm (1 1/4-in.) diameter iron pipe 75 cm
(30 in.) long, threaded to fit the cross. The cross is to be drilled with one hole 10 mm (3/8 in.) in diameter through the centre at right angles to both branches, with a bolt to fit. In operation, the handle is slid along the operating shaft, and is pinned through successive corresponding holes in the shaft.

The tripod may also be made of 1½-in.-diameter iron pipe or of wood or bamboo poles, as shown in Fig. 55. The pulley block, single sheave, for 20-mm (3/4-in.) rope will usually be sufficient. One auger guide as shown in Fig. 55 and 56 will also be required.

**Procedure**

The procedure to be used with the equipment described above is fairly standard all over the world. The following suggestions are offered by Mr J. C. Carter, of the International Health Division of the Rockefeller Foundation:

"(a) Set up the tripod over the spot where it is desired to bore the hole and attach the pulley block in place. (b) Directly under the pulley block, excavate a hole about 6 inches [15 cm] deep and of the same diameter as that of the auger. (c) Place the auger, equipped with shaft and turning handles, in the hole which has been excavated and adjust the turning handles to the desired height on the shaft. Lock the turning handles in place by the use of the set screw in the cross tee, or by the use of a steel pin if a round shaft is used. (d) Thread the hoisting rope through the pulley block and attach one end to the auger, or to the auger shaft. (e) Turn the auger in a clockwise direction until it is filled. Care must be exercised to ensure that the shaft is kept in a vertical position while turning until the hole is deep enough to put the auger guide into use. (f) When the auger is filled, lift it out of the hole by hauling on the hoisting rope, swing it to one side and empty it. Then let the auger swing back over the hole, lower it, and proceed as before. (g) When the hole has reached a depth of about 3 feet, place the auger guide in position and fix it in place by the use of an iron or wood peg at each corner. With the auger guide in place no further difficulty should be experienced in boring a vertical hole. (h) After the desired depth has been reached remove the auger from the hole and set the tripod aside. Insert the lining (if one is required) . . .”
THE BUCKET LATRINE

Description

This system of excreta disposal is also referred to as box-and-can privy, conservancy system, pail latrine, or earth closet in English-speaking countries, and as tinettes in French-speaking areas. In principle, it consists of a bucket in which excreta are deposited and which is removed for emptying and cleaning at frequent intervals (see Fig. 57). In the earth closet and tinette types of bucket latrines, a mechanical device is available from which dry earth, sawdust, or ash is released by the user to cover the excreta.

These types of latrine are in use in rural towns and urban areas without sewers in many countries of Africa, South-East Asia, and the Western Pacific. They were also used extensively in the past in Europe and the Americas but have almost completely disappeared in favour of better and more sanitary types of excreta disposal installations, especially the pit privy and the water-borne systems.

A = Iron pipes for tripod  
B = Iron pipe for auger shaft  
C = Plate  
D = Auger  
E = Cross-T and handles  
F = Pulley block  
G = Rope  
H = Auger guide
Design and Function of Its Parts

The bucket or receptacle

The bucket or receptacle is usually made of seamless galvanized iron, rubber, or white enamel. It is about 38 cm (15 in.) in diameter at the top and 30 cm (12 in.) deep and has adequate handles for lifting and carrying. In some cases it should be provided with a removable, tight-fitting lid held in place by clamps. It is the practice to make two buckets, painted different colours, available for each latrine hole or seat so that a clean pail may be placed in the latrine when the other pail is taken away for emptying.
The collection chamber and the superstructure

The bucket is placed in a collection chamber (or box) situated below the squatting plate (or seat). The chamber may be built of brick or concrete, with rounded corners and is so shaped as to help centre the pail. Most chambers open to the rear of the latrine, into the service lane used for collection. Where seats are used, the space beneath constitutes the box, and the pails may be removed through the hinged latrine seats. In any case, it is important from the sanitary standpoint that the collection chamber be fly- and animal-proof. Good practice also calls for ventilation of the chamber by means of a pipe vent carried to roof level of the superstructure. The vertical distance between the bottom surface of the floor slab and the rim of the bucket should not be greater than 2.5 cm (1 in.).

The superstructure itself is built in the same manner as for an ordinary pit privy, except that the floor is raised above the collecting chamber and the ground level. In some countries the floor is designed in such a manner as to separate solid faeces from urine and ablution water, which tend to fill up the buckets quickly and to keep their contents in a semi-liquid state. Urine and other liquid wastes are directed by troughs either to an impervious catchpit, which is emptied periodically, or to a soakage trench.

Collection and Conveyance of Buckets

Collections are usually made daily, although in some places they are made only weekly or bi-weekly. The collected pail should be sealed with a fly-tight lid and replaced by a clean and disinfected one of different colour (to facilitate routine sanitary inspection). It is sometimes emptied into a tank carried by a vehicle, and then taken away to be washed. The practice of emptying buckets into a tank or wagon and immediately returning them to the latrines must be unreservedly condemned. The time of collection, whether night or day, may be decided by the community concerned.

The method of transportation varies greatly among countries, from the coolies' "basket" system in the Far East to push-carts or bull-carts and to motor vehicles elsewhere. Care is seldom taken to avoid spilling the contents of the buckets during collection and transportation to the disposal grounds.

In Asian countries, the amount of night-soil (faeces and urine) collected per pail per day is roughly 4.5 l (1 Imp. gal.) ; in Ceylon, where faeces only are collected, the collection amounts to 1.4 l (0.3 Imp. gal.) per pail per day.

At the disposal site, the buckets are emptied, thoroughly washed, and disinfected with a phenol or creosol type of disinfectant before being stored away and re-used. The wash water is disposed of underground by means of soakage pits, and should not be permitted to run freely in
open ditches or used, without adequate control by local health authorities, for farm irrigation. It goes without saying that the disposal sites should be located as far away as possible from human habitations and all sources of drinking water.

The collection system is best carried out by the community administration and under the direct supervision of the health authorities. A fee is usually paid by the family for this service, and is sufficient to cover the costs of operation and replacement of the equipment.

**Methods of Night-Soil Disposal**

The methods of disposal of night-soil were reviewed at the previously mentioned WHO seminar on sewage disposal for South-East Asian and Western Pacific countries. The following is based on the report on that seminar.\(^a\)

Night-soil collected by the conservancy system may be disposed of by a number of methods, varying widely in efficiency, in sanitation, and in cost.

**Various methods used**

(a) The use of water transport, where available, to convey night-soil to its ultimate disposal point in a sufficiently large body of diluent water is acceptable from a public health standpoint. This is, however, relatively expensive and may become entirely inoperative during even moderate storms.

(b) Burial in earth pits or trenches, which has the advantage of being extremely simple, is rather common. It requires a considerable amount of hand labour.

(c) Incineration of night-soil along with other types of refuse fulfils sanitary requirements but is expensive.

(d) Detention in specially designed tanks is practised in some Asian countries in which it has long been the custom to use human excreta to fertilize growing crops. If the detention period is sufficient to permit the "die-away" of pathogens, public health criteria for using this material are met. The cost of this operation depends on the cost of storage and transport and the selling price of the material.

(e) In some countries, raw or partially decomposed night-soil is used for agricultural purposes. This practice, however, is universally condemned on public health grounds.

\(^a\) *Report on Seminar on Sewage Disposal (Rural and Urban)*, Kandy, Ceylon, 1955 (Report issued by the WHO Regional Office for South-East Asia, New Delhi)
(f) Disposal directly into sewers is practised in a number of urban areas throughout Asia. This is an accepted method of sanitary disposal if "depos" are properly constructed, maintained, and operated. It is a relatively inexpensive method but has the disadvantages of producing odours, placing shock loads on treatment plants, and sometimes creating septic conditions within sewers which produce deterioration of the sewers and sewer structures.

(g) The anaerobic digestion of night-soil in closed tanks is a relatively new disposal technique. Digestion plants may be designed and located so as to be used later as a part of proposed conventional water-borne sewage-treatment plants.

(h) Finally, experiments have been carried out, in Japan, on developing methods of heating night-soil for sterilization. One method that has been tried is using the strong heat from municipal refuse incinerators.

**Details of several methods**

1. Trenching—method (b)

   Costs of the pit or trenching technique include the cost of suitable land located at a reasonable distance from the collection points and the costs of labour and transportation.

   Sanitary considerations associated with this technique include subsoil conditions, the possible utilization of ground water for water supplies, gross contamination of surface waters, and depredations of domestic or wild animals.

   A common method of trenching at the present time is to use a trench 60 cm (24 in.) deep, filled with 45 cm (18 in.) of night-soil and covered with 15 cm (6 in.) of earth. This amount of coverage is considered inadequate for two reasons: (1) according to parasitologists, hookworms can work their way through 10-13 cm (4-5 in.) of soil; and (2) during monsoon weather, the bulking of the faecal matter can cause oozing through the cover. It is therefore essential that the trench should contain only 30 cm (12 in.) of night-soil, with a 45-cm (18-in.), tamped earth-cover, 15 cm (6 in.) of which is a mound of earth above ground level.

   The bottom of the trench should be above the highest water-table and preferably above the layer of soil likely to be moistened by capillary action. In areas of excessive rainfall a deeper trench should be provided, if possible. Grass may be grown to assist digestion and prevent erosion, so long as there are no cattle.

   The service life of trenching areas will vary from about two months (the time necessary for digestion) to two years (the time for which they are used in present normal practice). It is believed that further work on this problem may result in a reduction of this two-year service life. Service life, utilization, and land values are inter-related; and, if a reduction in
the trenching time were effected, less land would be required, and the area might be utilized in a better way.

2. Disposal into sewers—method (f)

Satisfactory depots for the disposal of night-soil into sewers should be located at convenient points away from very populous areas. The buildings should be fly-proof and always kept clean and sanitary. The public should not be allowed to enter the premises to obtain water or to wash clothes. An abundant water-supply under pressure is most important, and a storage tank of adequate capacity should be installed. Without water the night-soil would be inadequately flushed, the screenings exceedingly difficult to handle, and the condition of the pails, trucks, and depots a serious public health hazard. The receiving hopper should be made of concrete with rounded corners and should be installed with a bar screen, through which the night-soil may be flushed. A trap should be installed between the dumping hopper and the sewer main. In all water pipings, care must be taken to see that there are no cross-connexions or possibilities of back-siphonage.

The seminar participants did not endorse the collection of night-soil in lieu of the extension of sewers. They felt, however, that, where the practice had to be continued, collected night-soil could be disposed of into the sewer if proper precautions were taken to prevent damage to the sewer or interference with treatment processes.

3. Digestion plants—method (g)

The disposal of night-soil by digestion is being practised in Japan, where, in different areas, about 20 plants, to serve populations ranging from 3500 to 100,000, are under construction or in operation.

This process essentially involves the same digestion process of sewage sludge as occurs in conventional sewage-treatment plants; the digestion plants are usually designed so that they can become component parts of complete treatment plants when water-borne sewage schemes become possible.

The night-soil is carried to the plant by hand or by motor transport and is discharged through a screen chamber into the digestion tank. The containers are cleaned, and the wash-water goes into the digester. Digester gases are collected, stored, and used for maintaining the temperature of the digester contents at 30°C (86°F) for about 30 days. Digested sludge is withdrawn to drying beds, and dried sludge used as fertilizer. Supernatant liquors are diluted and treated by biofiltration. Screenings are usually incinerated.

A review of the operation of one group of seven digester installations indicated that they had capacities ranging from about 28 l to 39 l (1.0 cu. ft to 1.38 cu. ft) person served.
Operational and cost data are unfortunately not yet available for this method of night-soil disposal.

**Comments on the Bucket Latrine System**

In theory, a properly designed and operated bucket latrine system will fulfil all sanitary requirements. In actual practice this is far from being the case, and satisfactory conservancy systems anywhere in the world are rather rare exceptions. Experience gathered in every country shows that the bucket latrine system, though cheap in initial cost, is in fact the most expensive type of installation to operate and maintain. In addition, it has obvious health hazards for the community and for the scavengers, in particular; by its very nature, it inevitably leads to difficulties of a social nature because of the stigma attached to the scavengers who engage in this filthy type of work. In fact, in most countries of the world it is becoming increasingly difficult to recruit labour for scavenging. In rural areas it may still be possible to secure the co-operation of interested farmers for this job.

It has been noted that the use of dry earth, sawdust, or ash is often ignored even in areas where the latrine still bears the names of “dry earth closet” and *tinette*. As a result, the contents of the buckets are highly odorous and attractive to flies, which lay their eggs in them at the first opportunity. The door of the collection chamber and the squatting hole or seat are seldom fly-tight and closed. In spite of active supervision, the contents of buckets are often spilled carelessly near the latrines or along the road to the disposal site. The bucket lids are rarely kept in place; and it has been reported that, in a major town, the buckets are left exposed for hours without covers on sidewalks pending collection! The system, which depends on the separation of urine and faeces, is seldom built and maintained properly, as a result of which the urine simply runs over soaked ground and through unsightly pools. Conditions at the disposal sites are often intolerable due to spillage, lack of an abundant supply of water, intense fly-breeding, odours, and rodent infestation.

Owing to the enormous difficulties in operating this system in a sanitary manner, the bucket latrine usually violates most, or all, of the sanitary requirements set forth on page 39.

The cost of operation of the conservancy system is, in most instances, staggering, although not often so recognized by town councils. In countries of South-East Asia, present costs range from Rs. 20/– to Rs. 70/– (US $4.21 to $14.70) per pail per year for poor to “good” conservancy systems. In Hong Kong the cost is HK $56 (US $9.82). These are only direct operating costs of collection and disposal and do not include latrine structure, maintenance and replacement of pails and other transportation equipment, or gratuities to scavengers, which are additional costs borne by the family.
A rural community of 1500 persons, for example, having a conservancy system of 320 pails may be spending up to US $3200 per year for a never-ending insanitary excreta disposal system, without realizing that this annual cost could finance an immediate capital expenditure of US $41,600. This is calculated on the reasonably safe assumption that the community would reimburse this capital by equal instalments of $3200 a year for twenty years, the interest rate being 4.5%. It is strongly recommended that communities which possess conservancy systems should undertake a thorough sanitary and financial study of the operation of these systems with a view to changing them to better and more economical types of excreta disposal installation.

The only thing which may be said in favour of the bucket-latrine system is that it offers a means for collecting night-soil, which, in some areas, is ultimately used as soil fertilizer. There is, however, another type of latrine—the compost privy—which is better adapted to this purpose and which is described later.

THE “FEUILLÉES” OR TRENCH LATRINE

Description

In French-speaking countries, the term feuillées applies to very small and shallow pits dug into the top layer of the ground. The pit is usually square, about 30×30 cm (12×12 in.) in cross-section, and 40 cm (16 in.) deep. The excavated earth is piled loosely around the hole (Fig. 58). Each user is expected to throw a scoopful of loose earth over the faeces deposited. The urine normally falls outside the pit and drains away. It is estimated that a pit of this size will receive 100-150 droppings, after which it is thoroughly covered with an equal volume of earth. Under tropical conditions, the decomposition of faeces is completed in about eight weeks, and the resulting humus may be dug out and utilized to fertilize garden crops. A new hole is dug at a minimum distance of one metre (39 in.) away from the first pit and is used in the same manner.

The trench latrine operates under the same principle as the feuillées, i.e., the excreta are deposited in the top layer of the soil, in which the aerobic saprophytic bacteria are most numerous and active and reduce the offensive material in the shortest possible time (see p. 25 “decomposition of excreta”). The trench is often dug to a depth of 60 cm (24 in.), which is acceptable from the biological standpoint, with a length of about 1-3 m (3-10 ft).

While the trench latrine is designed for temporary use only in such places as military bivouacs, scout camps, temporary building or mining
sites and similar locations, *feuillées* are used as a permanent measure in rural and suburban areas, and even in urban areas of large towns, especially in Africa. The Bureau Central d’Études pour les Equipements d’Outre-Mer, Paris, France, in a publication dated February 1955, describes one type of *feuillées* applicable to soft ground (into which they are dug) and another type applicable to hard soil (over which they may be installed). An improved type has also been designed by this French government office and is described by Médecin-Général Sanner as follows:

"The system includes [Fig. 58]:

"(a) a pit $0.60 \times 0.40 \times 0.40$ m ($24 \times 16 \times 16$ in.);

"(b) above the pit a Turkish-type squatting plate provided with two foot rests, two handles, one hole, and one gutter to divert urine towards a small pit or a drain;

"(c) a rought superstructure;

"(d) an open box or pitcher full of loose earth.

"When the pit is full, it is covered with an iron sheet held in place with four stakes (against animals, rain run-off, and soil pollution with worm larvae); and the squatting
plate and superstructure are moved over another hole. After six to eight weeks, the iron sheet may be removed, the faeces having been transformed into humus and pathogens having been destroyed. Squatting plates of this type may be built of wood, metal, or concrete. They could be mass-produced and given away to poor communities following proper health education of the people as to their use.” [Trans.]

Advantages and Disadvantages

Feuillées and trench latrines offer serious disadvantages and health hazards for villagers and rural communities as a whole. The improved type of feuillées described above might constitute a considerable sanitary improvement and might be used in rural areas if the people could reasonably be expected to observe faithfully the few steps involved in the latrine’s construction and operation, especially the step which prescribes the covering of the full pit with an iron sheet for a period of two months. General experience with respect to hole covers in latrines, the maintenance and operation of the bucket latrine system, and the possible alternative uses of sheet metal in villages leads one to believe that, despite routine inspection and supervision, the full pits would not be kept covered in the majority of instances.

The most significant hazards caused by these latrines are:

(a) the inevitable pollution of the soil surrounding the feuillées or the trench latrine, since there is virtually no protection against the access of worm (especially hookworm) larvae to the ground surface;

(b) the breeding of flies in enormous numbers, and the access of flies and animals to uncovered or lightly covered faeces in the pits;

(c) the danger of pollution of both surface and ground water;

(d) the easy access to and scattering of the material by rodents and other animals.

To these may be added the odour nuisance and, from the aesthetic point of view, the unsightly conditions generally attached to these types of latrine. On the credit side, it may perhaps be said that they are easy and cheap to build and fit in well with the primitive habits of village folk in many areas. However, in countries where they are used, the cost of sickness and debility and the losses of productive power and of life-capital through premature death generally are a heavy burden not only on the people concerned, but also on whole regions and their governments. Often the actual value of these losses cannot be assessed. In one instance at least, the feuillées system has shown how expensive it can be: in a large city in Africa comprising densely populated suburbs where the feuillées had been adopted, chemicals (DDT, diazinon, etc.) were sprayed regularly from the air, at a heavy cost to the health authorities, in an attempt to reduce the enormous fly infestation over the whole city.
Both the feuillées and the trench latrine occupy a place among excreta disposal installations as temporary devices to be used by moving groups of individuals for a few days at a time.

THE OVERHUNG LATRINE

The overhung latrine consists of a superstructure and a latrine floor built on top of wooden piles above water along the banks of rivers, sea beaches, or coastal flats. This type of latrine, which is found occasionally around seaports and fishing villages in every continent, is very common in large coastal areas of Asian countries. The severity of the health problems raised by this system of excreta disposal was recognized by the participants in the WHO-sponsored seminar on sewage disposal, in the report on which the following views were expressed:

Throughout Asia many people are forced to inhabit land areas that are frequently or periodically covered with water. The coastal fishing villages where, it is claimed, some adults have never set foot on solid ground would be typical examples. For people living in raised huts with cat-walks for streets, the problem of the disposal of human excreta has rarely been given thought or attention. In the case of brackish rivers or tidal flats, drinking-water is difficult to obtain; most of the inhabitants rely on rain-water or carry well-water from some distance by small boats. The health hazards under such conditions are difficult to evaluate, especially in the light of the existing knowledge of the epidemiology of certain environmental diseases.

Under such circumstances a carefully located “overhung” or “drop” latrine might be the only measure which could be applied. Such a latrine might be acceptable, provided the following general conditions are met:

1. the receiving water is of sufficient year-round salinity to prevent human consumption;
2. the latrine is installed over such water depth that the bed is never exposed during low tide or the dry season;
3. every effort is made to select a site that will provide for carrying floating solids away from the village and will furnish dilution;
4. there is a stream flow of 14 l (0.5 cu. ft) per second per family for adequate dilution;
5. the walkway, piers, squatting openings, and superstructure are made structurally safe for adults and children.

\* Report on Seminar on Sewage Disposal (Rural and Urban), Kandy, Ceylon, 1955 (Report issued by the WHO Regional Office for South-East Asia, New Delhi)
There was reluctance on the part of the seminar participants to give support to this technique, however. This reluctance was based on:

(a) the relatively long survival rates of pathogenic organisms in fresh and brackish tropical waters;

(b) the universal habit of prolonged contact with water in bathing and fishing; and

(c) the possibility that the practice of using this type of latrine would become established upstream, where it would empty into smaller and fresh-water courses.

Such latrines should be considered only in places where the conventional terrestrial type cannot be built. (It is recognized, however, that reluctance to accept the overhung type of latrine, when properly situated and constructed and discharging into a stream or harbour of sufficient flow, is not entirely consistent with the accepted practice of urban sewage disposal by dilution.)

It should be stressed that the practice of drinking from any surface stream in the populated areas of Asia is not safe at present, and that surface waters are expected to become progressively more contaminated as cities and towns become more highly developed and populated.

THE COMPOST PRIVY

Use of Night-Soil as Fertilizer

The use of night-soil as soil fertilizer has been studied by several scientists, in particular by Gotaas and Scott in recent publications. Scott states that in many countries of the Western Pacific "faecal-borne diseases are very definitely related to agricultural practices in that night-soil is used as fertilizer". Both authors point to the important relationship between sanitation and agriculture in all parts of the world and review modern composting methods which are capable of producing a safe and valuable fertilizer from mixtures of human and village wastes. Many investigations cited by these authors have shown that pathogenic bacteria and worm eggs are unable to survive temperature conditions and biological antagonisms prevailing during composting processes. In rural areas where from time immemorial excreta have been used by the farmer, it is recommended that health authorities work hand in hand with those concerned with agricultural development in order to solve the problems involved in the safe utilization of human wastes.

As has been previously noted, one problem which has not yet found a satisfactory solution is the collection and transport (i.e., handling) of
night-soil from the latrine to the composting site. The health hazards involved in these operations are considerable, not only for the scavenger group, but also for the whole community; and they cannot be ignored by either health or agricultural authorities. Because of these hazards, modern composting procedures, which would make possible the recovery of the vast amounts of plant nutrients contained in human faeces and urine cannot yet be applied everywhere.

In urban areas of many countries, pit privies, vault and aqua privies, and septic tanks are periodically emptied by mechanical means, generally by use of a closed metal tank, carried by a truck, into which the liquid and semi-liquid faeces are pumped. The truck may even carry the water necessary for liquefying the solid contents of the latrines. Such an operation is, of course, expensive in initial cost and not readily applicable to every rural area of the world.

The collection and transportation methods involved in the so-called conservancy or bucket-latrine system cannot be recommended, for reasons already discussed. There is a great need for further research and field experiments to discover an economical and adequate solution to this sanitation problem. It is very likely that, when such a solution is found, human wastes from over a billion rural inhabitants will be returned to the soil to fertilize it for the benefit of mankind.

**Description and Operation of the Compost Privy**

A reasonably safe way for a villager to prepare excreta for use as fertilizer is for him to compost it in a privy pit. After the required period of composting, the pit can be emptied, thus eliminating the handling of the raw excreta.

The privy pit, slab, location, and other features would be no different from those described above (pp. 42-68) for the pit privy. However, the compost privy should be provided with the largest possible capacity so that it will not fill too fast. For this reason it may be necessary to enlarge the cross-section of the pit. This may be done by using a large, four-part, concrete slab as shown in Fig. 28, or by giving the pit an oblong shape, in which case part of the vault extends outside of the superstructure and is covered with a tight-fitting and durable cover. A pit 80 cm (32 in.) wide, 1.80 m (6 ft) long, and 2.50 m (8 ft) or more in depth may be used for the compost privy.

The method is a modification of the Bangalore composting process and is based on anaerobic decomposition of organic wastes which are left undisturbed during a period of at least six months to ensure destruction of pathogens and ova of helminths. The procedure would be as follows:
1. Dig a pit of required size, the bottom of which should always be above ground-water level.

2. Before the slab is placed, cover the bottom 50 cm (20 in.) of the pit with grass cuttings, fine leaves, garbage, paper, etc.; but allow no rubbish such as metal cans, glass bottles, or similar materials to be deposited therein.

3. Place slab, and complete superstructure, keeping in mind that they will both be moved periodically to another site.

4. In addition to depositing human excrement, throw the daily garbage into the pit, along with cow, horse, sheep, chicken, and pig manure, as well as urine-soaked earth or straw. The latter materials are important, as urine is rich in nitrogen, an essential plant nutrient.

5. About once a week throw a few kilograms of grass clippings and fine-texture leaves into the pit. After some experimentation, one can arrive at a pit mixture which will provide a good fertilizer.

6. When the pit’s contents reach a level 50 cm (20 in.) below ground, a new pit is dug 1.50-2 m (5-6.5 ft) away (more if desired), and the superstructure and slab are moved over it. The first pit is levelled, finally, with 15 cm (6 in.) of grass clippings and leaves, and the top 35 cm (14 in.) with well-tamped earth.

7. When the second pit is filled as indicated above, the first pit is uncovered and the compost removed. It should be stable, and will provide a good fertilizer which can be applied immediately to the fields or stored.

The volume of the pit depends on the needs for fertilizer and the number of people using the privy. The proportion of night-soil that can be added to refuse for satisfactory composting should be about 1 to 5 by volume. From the data given above (pp. 43-48), it will be noted that a family of five will produce, on the average, one cubic metre (35 cu. ft) of partly digested excreta in about four years. On this basis, one-fifth of a pit of one cubic metre (35 cu. ft) capacity would be filled with excreta in approximately 9-10 months, which would be a good composting cycle for such a pit. (The other four-fifths of the contents would consist of refuse and other wastes thrown in as explained above.)

Before applying or recommending this method in a rural area where it is not familiar, it is desirable to try it first on a pilot scale under adequate control in order to determine the proper operating schedule and materials suitable and available in the area under consideration. The collaboration of agricultural officials and of local leaders among the farmers of the area is necessary.

To obviate moving the superstructure and slab back and forth over two separate pits, the system may be amended by building what may be
called a "double-vault" latrine (see Fig. 59). This latrine consists of a large vault divided into two compartments, each of which is topped by a slab and a hole. The superstructure is likewise partitioned into two houses with separate entrances. In practice, the vaults are filled and emptied alternately in the same manner as described above for the compost privy. They should be large enough to allow sufficient time for the materials to compost thoroughly before their removal. The vaults need not be water-tight but should be built well above the ground-water
table. The difficulty with the double-vault privy is that often both compartments are used simultaneously, thus defeating their purpose. Constant inspection and advice by health and agriculture staff are necessary.

Advantages and Disadvantages

Proper composting in privy pits is rather complicated and may well be, in the beginning, beyond the comprehension of most rural families. Close supervision by health and agriculture officials and systematic education and follow-up are required during the first two or more years of application. Furthermore, privy pit composting is not free of hazards and requires attention. Proper placement is essential to prevent pollution of ground water supplies and the entrance of water into the pit.

Under proper conditions of operation, this method will satisfy most sanitary requirements laid down on page 39. It is, of course, somewhat more expensive than the ordinary pit privy since it involves the construction of two or more pits. One further disadvantage is the loss of a portion of the liquids (especially urine), which seep away into the ground, carrying with them nitrogenous matter held in solution. However, it offers a reasonable means of conserving most of the fertilizing value of excreta with a minimum of health risks.

THE CHEMICAL TOILET

Description

The chemical closet consists of a metal tank containing a solution of caustic soda. A seat with cover is placed directly over the tank, which is ventilated by a flue rising through the house roof (see Fig. 60). The tank is made of a special steel alloy capable of withstanding corrosion and has a capacity of about 500 l (110 Imp. gal.) for each seat served by it. A charge of 11.3 kg (25 lb.) of caustic soda dissolved in 50 l (11 Imp. gal.) of water is applied to the tank for each toilet seat. The excreta deposited in the tank are liquefied and sterilized by the chemical, which also destroys all pathogens and worm eggs. To facilitate this action, the tank is usually provided with an agitator which helps to break the solids and to speed their disintegration by the chemical. After several months of operation, the spent chemical and the liquefied matter are drained or removed and are deposited in a leaching cesspool, suitably located.

This toilet is non-odorous and suitable for use inside dwellings, isolated houses, schools, etc. It is also employed in the form of a movable commode of about 40-l (9 Imp. gal.) capacity on boats, aircraft, motor caravans,
and other vehicles. It is obtainable from commercial establishments and is fairly expensive in initial cost and in operation.

Advantages and Disadvantages

With proper operation the chemical toilet is a very satisfactory type of excreta disposal installation which fulfils all sanitary and aesthetic criteria. It has the further advantage that it can be placed inside the dwelling.

The primary disadvantage is its price and the recurring cost of the chemical. It does require attention and will not stand up to abuse. Only toilet paper (and no other rubbish) should be thrown into it. If poorly operated and maintained, which is usually the case when the chemical is spent and not immediately replaced, there are odours and an increasing amount of floating matter over the liquid contents of the tank. For these reasons, the chemical toilet cannot be used at present in most rural areas of the world.
WATER-CARRIED METHODS OF EXCRETA DISPOSAL FOR RURAL AREAS

SOME PROBLEMS IN THE DISPOSAL OF WATER-BORNE WASTES

General Considerations

Experience has shown that, when running water is available, the water-carried system of excreta collection and disposal is most satisfactory and convenient under both urban and rural conditions. It fulfils all sanitary and aesthetic criteria. In particular, contamination of the soil and of surface water is avoided; potentially dangerous wastes are rendered inaccessible to flies, rodents, and domestic animals; and the mechanical transmission of faecal-borne diseases to man is prevented.

One serious disadvantage, however, is the difficulty of disposing of the large volume of wastes resulting from the addition of water. While in cities the liquid wastes are usually carried away by means of sewers, in most rural areas of the world sewerage systems do not exist, and liquid wastes are conveniently discharged into the ground. Since in such areas ground water is often tapped as a source of domestic water-supply, there is an obvious need for proper location and construction of the excreta disposal system, with a full understanding of the hazards involved (see p. 32).

Such a situation is frequently found in suburban areas, in which case the possibilities of linking up the drainage of these areas with the public sewerage of the near-by town should first be investigated. Individual waste disposal is often more costly and troublesome in the long run than public sewerage. In densely populated rural areas of some countries in Europe and North America, the sewerage problems of communities sufficiently close to each other have been solved through the creation of special "sewer districts" administered in common by the municipal authorities concerned.

In developing rural villages and communities with scattered dwellings, it may be desirable for the local government to take the initiative and responsibility in order to ensure the adoption and construction of the most satisfactory installations, keeping in mind future conditions in the
developed and fully inhabited areas. In some instances, the government may decide to undertake the planning, construction, management, and supervision of the individual sewage disposal systems. This procedure is not recommended for application in rural areas, for reasons already explained. However, satisfactory waste-disposal will be achieved by individual families if the local health authorities are prepared to supply the necessary guidance and the continued attention and supervision after the facilities are installed.

Various methods may be used in rural areas to dispose of liquid wastes. They include disposal by dilution in large bodies of water, the use of cesspools and seepage pits, and the septic-tank systems, which involve settling tanks with single or multiple compartments followed by subsurface irrigation fields, filter trenches or sand or trickling filters. Selection of methods will depend primarily upon the degree of sewage treatment to be provided, upon the location of the system and other local factors, and, finally, upon costs. Local factors which bear upon the selection and design of the disposal installation include, among others, the nature of soil formations, the presence and levels of ground water and the direction of flow, topography, the proximity of sources of water supply, the quantity of sewage, and the area available for the disposal works.

Disposal by Dilution

Where large bodies of surface water, such as the sea, lakes, or large rivers, are available nearby, the liquid wastes from dwellings or communities may be discharged into such waters directly or after septic-tank treatment only. The outfall pipe conveys the sewage to a point well below the lowest water or sea level, preferably near the bottom of the receiving water, in order to ensure adequate dilution of the warmer and lighter sewage, which will normally rise and disperse through the diluent water body.

This system of disposal is designed to take advantage of the natural ability of water for self-purification, which is based primarily on the availability and amount of oxygen in solution in the receiving water. This oxygen reacts with and stabilizes the organic matter in the sewage by oxidation. If there is not enough oxygen in the receiving water or if the volume of this water is too small to supply the quantity of oxygen required, anaerobic decomposition will begin and proceed at such a pace that the normal biological balance of the water may be upset. As a result, the receiving water will become foul and black, and its normal fauna (especially the fish, which require oxygen to survive) will be totally destroyed.

Another hazard created by the disposal of sewage in this manner is the possibility of contamination of the receiving water with pathogenic
bacteria and the eggs and larval forms of harmful helminths, such as those of bilharziasis and liver flukes. In rural areas where such water is used for bathing, washing clothes, irrigation of foods to be eaten raw, and other purposes, the dangers involved are obvious. This explains why liquid wastes from rural dwellings, institutions, or communities should never be discharged into public bodies of water without the permission of local health authorities. Where the objective is simply the avoidance of nuisance, health authorities usually prescribe the desirable ratio of volume of sewage with respect to the amount of receiving water. For natural waters, the amount of sewage should not be more than one-twentieth to one-fortieth of the amount of water flowing.  

The Cesspool

A cesspool is essentially a covered pit which receives raw sewage. It may be of the water-tight or of the leaching type. In some cases, especially in Europe, it is made water-tight and is designed to hold the liquid wastes, which must be removed periodically, about every six months. The leaching cesspool, on the contrary, is dug into pervious soils in order to allow the liquid portion of the waste to seep off into the ground. The solids then accumulate in the pit and gradually seal the pores of the ground.

Water-tight cesspools are usually designed for a capacity of 68 l (15 Imp. gal.) per person per month, or 408 l (90 Imp. gal.) per person when they are emptied every six months. Leaching cesspools have diameters of 90 cm (36 in.) or more, and are provided with an open-joint lining below the inlet level (see Fig. 61). The top part of the lining, which is within 60-90 cm (2-3 ft) of ground level, should be impervious and laid with mortar. Covers with inspection manholes are usually provided. After the pores of the ground become clogged and the pit fills, an outlet tee and an overflow pipe lead the supernatant liquid to a seepage pit.

As previously stated (p. 32), a cesspool should be located downhill from a well; in any case, a distance of 15 m (50 ft) will prevent bacterial pollution of the well. To prevent chemical pollution, too, the distance between a well and a cesspool placed directly uphill from it should be not less than 45 m (150 ft). Cesspools of the leaching type should be located at least 6 m (20 ft) away from dwelling foundations. Their construction is not permitted by health authorities in densely inhabited communities where wells are used as sources of drinking-water supply.

The Seepage Pit

The seepage pit receives the effluent from aqua privies, cesspools, and septic tanks and allows it to percolate away into the ground. It is sometimes used for the disposal of laundry, bathroom, and kitchen wastes.
In the latter case, a grease trap may be necessary on the house sewer-line. The seepage pit may also be built at the lower ends of subsurface disposal tile lines in order to catch the septic-tank effluent which may have gone through without percolating away.

As shown in Fig. 62, the seepage pit consists merely of a round hole in the ground dug deep enough to penetrate 1.8 m (6 ft) or more into a porous layer of the earth. Diameters of 1.0-2.5 m (39-100 in.) and depths of 2.5 m (7-16 ft) are common. The side walls are lined with bricks or stones laid without mortar below the level of the inlet pipe. The hole may be filled with stones, in which case a lining is not required. The seepage pit should be closed with a tight cover which will prevent access to mosquitoes and flies and to surface water as well.

If the soil through which the pit has been dug is not sufficiently porous, the effluent will slowly accumulate and will ultimately overflow. Even
in porous soils such a situation is common, as the pores of the earth walls become choked by the deposit of the finely divided matter carried by the effluent and by the solids built up by the life activities of zoogloeoal organisms which thrive on the grains of the soil in contact with this effluent. These phenomena, in fact, govern the life span of a seepage pit, which should normally last for several years (perhaps 6-10 years) if the effluent is only slightly turbid as a result of efficient primary treatment of the raw sewage.

When a seepage pit ceases to operate, a new one should be dug several metres away. In order to increase the life span of the disposal system, it is possible to dig two or three seepage pits and to connect them at the top. The distance between any two pits should be at least three times the diameter of the larger pit.

The obvious disadvantage of seepage pits is the danger of pollution of ground water. For this reason they should be carefully located; the general rules governing their location have already been discussed (p. 32). It will be recalled here that seepage pits should preferably be located downhill and, in any case, at least 15 m (50 ft) away from drinking-water sources and wells. As in the case of cesspools, the construction of seepage pits is not usually permitted by health authorities in closely built communities where ground water is used for domestic purposes.

THE SEPTIC TANK

The septic tank is the most useful and satisfactory unit among all water-carried systems of disposal of excreta and other liquid wastes from individual dwellings, small groups of houses, or institutions located in rural areas out of reach of sewer systems. It consists of a covered settling tank into which the raw sewage is led by the building sewer (see Fig. 63-65). The processes which take place inside the septic tank constitute the
"primary treatment" of the raw sewage, and those which occur in the disposal field form the "secondary treatment". It should be noted that all liquid wastes, including those from bathrooms and kitchens, may be sent to the septic tank without endangering its normal operation. Recent research has shown that, contrary to former belief, sullage wastes can and should be discharged into septic tanks.

**FIG. 63. TYPICAL LAYOUT OF SEPTIC-TANK SYSTEM**

- A = Private house or public institution
- B = House sewer
- C = Building sewer
- D = Grease interceptor on pipe line from kitchen
- E = Manhole
- F = Septic tank
- G = Dosing chamber and siphon
- H = Pipes laid with tight joints
- I = Distribution box
- J = Drop-boxes or terracotta L's
- K = Absorption tile lines
- L = Seepage pit, when required
- M = Slope of ground surface
- N = Topographic contour lines
**The Biological Processes Involved**

**Primary-treatment stage**

In the tank, the incoming sewage is held quiescent, being retained for a period of one to three days, according to the tank capacity. During this period the heavier solids settle to the bottom as sludge. Most of the lighter solids, including grease and fats, remain in the tank and form a scum over the water surface, while the rest is carried away by the effluent into the final disposal system.

The solids which are retained in a septic tank undergo anaerobic decomposition through the activity of bacteria and fungi. The significant result of this process is a considerable reduction in the volume of sludge,
which allows the tank to operate for periods of one to four years or more, depending upon circumstances, before it needs to be cleaned. This decomposition involves not only the sludge, but also the dissolved and colloidal organic content of the sewage.

The effluent of a properly designed and efficient septic tank is only slightly turbid, due to finely divided solids in suspension, and has a relatively low biochemical oxygen demand (BOD). However, it is still offensive in character; on standing, it yields little sediment but has a characteristic, putrid odour. In addition, this effluent is potentially dangerous to health, as it may contain pathogenic bacteria, cysts, and worm eggs which have passed unharmed through the tank during the relatively short detention period.

As the sludge decomposes, gas is produced and constantly rises to the surface as bubbles. The gas bubbles carry with them particles of decomposing organic matter which inoculate the incoming sewage with organisms which are necessary for putrefaction. These particles reach the scum which, in time, becomes thick and heavy and partly sinks below the water level. The floating cover of scum may attain such dimensions that its lower surface extends into the main sewage current. This usually coincides with a thick accumulation of dense and compact sludge over the bottom of the tank. As a result, the flow-through section becomes so small that adequate sedimentation of the suspended matter is no longer possible. At that time large amounts of floating matter will be noticed in the effluent. This condition can be prevented by regular cleaning of the tank.

The bubbling of gas through the liquid interferes to a certain extent with the normal sedimentation of sewage solids. This interference may be minimized by the addition of a second compartment to the septic tank. The lighter, suspended solids carried from the first compartment find quieter conditions for settling in the succeeding compartment. This is especially valuable at times of rapid anaerobic decomposition when sludge solids are found in greater quantity in the tank’s first compartment. The sludge in the succeeding compartment is usually more homogeneous and floculent than that in the first compartment, and there is also less scum production. The effluent of such a tank will contain a lower proportion of suspended matter than that from a single-compartment system.

For the efficient development of the biological processes, turbulence should be avoided, and the disturbing effects of surge flows should be reduced to a minimum. Turbulence and surge flows may be so serious in small or overloaded tanks as to cause a complete breakdown of tank operation and of secondary-treatment processes. The space available for clarification in the larger tanks has a certain compensatory or equalizing effect.

In order to ensure and to speed up the establishment of the biological processes at a high level of efficiency, newly constructed septic tanks are usually seeded with a quantity of ripe sludge bailed out from another tank already in operation. This sludge, which is in an advanced state
of decomposition, provides the bacteria and fungi necessary for rapid alkaline fermentation, which succeeds the initial breakdown of the raw organic matter by anaerobic bacteria. The addition of yeast is not effective in starting digestion in a new tank or in rejuvenating a sluggish tank.

Secondary-treatment stage

The secondary treatment of septic-tank effluent is based on the oxidation of organic matter through the activity of aerobic bacteria. These bacteria thrive in the upper layers of the soil and in sand or stone beds whose pores are naturally aerated by oxygen from the air. In subsurface irrigation and in filter beds, the effluent is spread as uniformly as possible over the grains of soil or sand, or over small stones. A biological slime develops in which the aerobic bacteria and micro-organisms are active. It is important that these biological media should not be overloaded or submerged for any great length of time; otherwise, the aerobic bacteria will die and anaerobic conditions will develop. In larger installations, aeration is achieved by intermittent dosing by means of a dosing siphon installed next to the septic tank. In this way, the soil or filter bed recuperates, and air penetrates anew in the interstices of the filtering medium during the intervals between flushes of the siphon. Natural aeration of the soil is facilitated in the case of filter trenches through the drain pipes and, in the case of subsurface irrigation, through a vent pipe or seepage pit installed at the lower end of the disposal field.

Ventilation of the filtering medium may be arrested if the pores are allowed to become clogged by suspended matter carried by the effluent or by excessive slime growths. In either case, the trouble may be traced to defective or inefficient operation of the septic tank itself, although excessive slime growth may also be due to overloading of the disposal field. In subsurface irrigation in particular, the need for efficient primary treatment and a clear effluent is greatest. Of course, much depends upon the porosity of the soil, fine-grained sand being best from the standpoints of both permeability and ventilation; impervious soils, such as clay, are totally inappropriate. Where ground water is close to the surface, it may not be possible to dispose of the effluent through subsurface irrigation, since the pores of the soil above the water table are clogged with water held by capillary action. Experience shows that tile pipes should not be laid closer than 90 cm (3 ft) to the ground-water level.

Design of the Septic-Tank System

The grease interceptor

Liquid wastes from large kitchens, such as those found in hotels, small hospitals, and similar institutions, are likely to contain much grease, which
may pass through the septic tank along with the effluent and may clog the pores of the filtering medium of the disposal field. In such cases, a grease interceptor is installed outside the building just before the building sewer (see Fig. 66). It is designed as a small skimming tank provided with submerged inlet and bottom outlet. Its operation is based on the principle that the incoming liquid waste is warmer than the sewage already in the interceptor and is cooled by it, causing the grease content to congeal and rise to the surface, from which it is skimmed off and disposed of by burial at periodic intervals. For this reason, grease interceptors should be easily accessible for inspection and cleaning.

Grease interceptors are not considered necessary in sewage disposal systems for dwellings and other small installations. Their size depends on the type of building and the volume of sewage to be handled. For a single-family dwelling (when it is desired to install one), the interceptor capacity should be about 110 l (30 US gal.). Other interceptors should preferably have a capacity equal to five times the volume of waste water that is liable to be discharged into them at any one time. They may be constructed of metal, brick, vitrified or concrete pipe, or concrete. The inlet and outlet should be placed as far apart as possible in order to avoid
a direct flow between them, and the depth below the outlet flow line should not be less than 60 cm (2 ft).

The building sewer

The U.S. Joint Committee on Rural Sanitation has the following recommendations to make:

"The building sewer is that part of the horizontal piping of a building drainage system extending from a point usually 5 feet [1.50 m] outside the inner face of the foundation wall to the public sewer connection or individual sewage disposal unit (septic tank, cesspool, or other type of disposal).

"The building sewer should be constructed of bell and spigot pipe made of cast iron, vitrified clay, concrete, or other durable material. Portland cement mortar or bituminous compounds should be used for all joints on pipe lines other than cast iron; lead or other suitable joint material should be used on all cast-iron pipe lines. Where the septic tank or primary unit of the disposal system is located within 25 feet [7.50 m] of the building or dwelling, it is desirable to construct the building sewer of extra heavy cast-iron pipe throughout its entire length because cast-iron lines are less susceptible to clogging and are easier to clean. Vitrified clay or concrete pipe should not be used in sizes smaller than 6 inches [15 cm]. When cast-iron pipe is used in the building sewer it may be the same diameter as that of the building drain, provided that it is not smaller than 4 inches [10 cm] in diameter. Whenever the building sewer is a different size than the building drain the connection therewith should be made with the proper type increasing fittings, assuring a watertight joint and satisfactory construction to eliminate clogging at the connecting point.

"All joints on the building sewer should be made by using a ring of oakum (jute) and such joint material to provide water tightness. Whenever the building sewer line is laid within root-growing distance of large trees or dense shrubbery and constructed of material other than cast-iron pipe with lead-caulked joints, the joints should be made with a bituminous compound or other root-proofing material. Special copper rings may be used with cement mortar or the cement mortar may be treated with copper sulfate or coarse salt to prevent roots penetrating the joints, entering the pipe line, and eventually clogging the sewer.

"The most essential features to be observed in construction of the building sewer line are as follows:

1. Minimum size of pipe: 6 inches [15 cm] if sewer is of vitrified clay or concrete, 4 inches [10 cm] if sewer is of cast iron.

2. Minimum grade—1 percent ... However a fall of [2 percent] is preferable and should be provided wherever feasible.

3. Grade of building sewer for 10 feet [3 m] immediately preceding the tank should not exceed 2 percent approximately...

4. Cast-iron pipe with lead or other comparable joint material used when within: 50 feet [15 m] of a well or suction line from a well, 10 feet [3 m] of any drinking water supply line under pressure, 5 feet [1.50 m] of basement foundations, and when laid beneath driveways with less than 3 feet [90 cm] of earth cover.

5. Cleanout at every change in line of 45° or more and at every change in grade in excess of 22½°. Bends of 90° should be avoided wherever possible or such bends made with two 45° ells or a long-sweep quarter curve. (Cleanouts are desirable within 5 feet [1.50 m] of the septic tank where tanks are located more than 20 feet [6 m] from the building. An economical cleanout may be provided by inserting a tee in the line with
the vertical leg extending to ground level and plugged with a brass cap. If the line is deeper than 4 feet \([1.20 \text{ m}]\), manhole construction should be required for cleanout purposes.)

"6. All joints made watertight and protected from damage by roots wherever necessary."

**The tank**

A review of the literature shows a multiplicity of designs adopted in various countries for septic tanks. Many of the designs recommended for dwellings and small institutions are cumbersome and complicated unnecessarily by the provision of special features claimed to achieve a better effluent. As a result of extensive research carried out between 1947 and 1953 by the United States Public Health Service,\(^3\) \(^{39}\) \(^{40}\) most of the problems involved in the design of septic tanks have been clarified. The following information includes several of its findings, in addition to data resulting from well-accepted practice in the USA,\(^37\) Europe,\(^23\) and elsewhere.\(^29\)

**Size of tank**

The principal factors to be considered in deciding on the capacity of a septic tank are:

(a) the average daily flow of sewage;
(b) the retention period, from 1-3 days, usually 24 hours;
(c) adequate sludge storage, for desludging every 2-3 years.

The average daily flow of sewage depends on the average water consumption in the area under consideration. In rural areas and small communities the water consumption per person is likely to be lower than in municipalities. As a result, sewage flows of less than 100 l (26 US gal.) per person per day may be expected in most rural areas of the world. However, experience indicates that such low figures cannot be used for the design of small septic tanks, which should be provided with ample capacity since such tanks are seldom cleaned before trouble develops. It is therefore important that their capacity be ample to permit reasonably long periods of trouble-free service and to prevent frequent and progressive damage to the effluent absorption systems due to discharge of sludge by the tanks. For this reason the capacity of residential, single-chambered, septic tanks should not be less than 1900 l (500 US gal.) below water-level.

The liquid capacities of the septic tanks described in Tables VIII and IX are based on a sewage contribution of:

- 190 l (50 US gal.) per person daily in dwellings;
- 95 l (25 US gal.) per person daily in camps;
- 64 l (17 US gal.) per person daily in day schools.
TABLE VIII. REQUIRED CAPACITIES * FOR SEPTIC TANKS SERVING INDIVIDUAL DWELLINGS

<table>
<thead>
<tr>
<th>Maximum number of persons served</th>
<th>Nominal liquid capacity of tank (US gal.)</th>
<th>Recommended dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>width</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ft</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>600</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>750</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>900</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>1100</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>1300</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>1500</td>
<td>4</td>
</tr>
</tbody>
</table>

* Liquid capacity based on number of persons served in dwelling. The volume based on total depth includes air space above liquid level.

The capacities indicated in Table VIII should in most countries provide sufficient sludge-storage space for a period of two years or more, and an additional volume equal to the sewage flow for 24 hours.

It should be noted, however, that in a few countries, small garbage grinders are being installed more and more frequently in the kitchens.

TABLE IX. REQUIRED CAPACITIES FOR SEPTIC TANKS SERVING CAMPS AND DAY SCHOOLS

<table>
<thead>
<tr>
<th>Maximum number of persons served</th>
<th>Nominal liquid capacity of tank (US gal.)</th>
<th>Recommended dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>camps</td>
<td>day schools</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>60</td>
<td>1000</td>
</tr>
<tr>
<td>80</td>
<td>120</td>
<td>2000</td>
</tr>
<tr>
<td>120</td>
<td>180</td>
<td>3000</td>
</tr>
<tr>
<td>160</td>
<td>240</td>
<td>4000</td>
</tr>
<tr>
<td>200</td>
<td>300</td>
<td>5000</td>
</tr>
<tr>
<td>240</td>
<td>360</td>
<td>6000</td>
</tr>
<tr>
<td>280</td>
<td>420</td>
<td>7000</td>
</tr>
<tr>
<td>320</td>
<td>480</td>
<td>8000</td>
</tr>
</tbody>
</table>

Note: Tanks with capacities in excess of 8000 gallons should be designed for the specific requirements involved; however, in such cases the necessity for a more complete type of treatment should receive consideration.
of dwellings for the purpose of grinding garbage or wastes, which are then discharged into the house sewers. This adds an appreciable load of settleable organic solids to the sewage and to the septic tank. Where such grinders are used, the capacity of the septic tank should be increased by 50% to allow for additional sludge-storage space.

The capacities shown in Table IX are based on a 24-hour flow of sewage without allowance for sludge-storage space, since it is expected that septic tanks serving camps and schools will receive regular inspection and maintenance, including more frequent cleaning than those for residences.

In the case of public institutions, such as rural hotels and hospitals, and groups of houses, such as housing projects, the figures given in Tables VIII and IX may not apply. It will first be necessary to secure the advice of a competent engineer whose duty it will be to determine the probable daily water consumption and sewage flow, both of which are likely to be much higher than the figures cited above. Most recent information indicates that:

1. For flows between 1900 l and 5700 l (500 US gal. and 1500 US gal.) per day, the capacity of the septic tank should be equal to at least 1½ days’ sewage flow.

2. For flows between 5700 l and 37 850 l (1500 US gal. and 10 000 US gal.) per day, the minimum effective tank capacity should be 4260 l (1125 US gal.) plus 75% of the daily sewage flow, or:

\[ V = 1125 + 0.75 \, Q \]

where

\( V \) is the net volume of the tank in US gallons, and \( Q \) is the daily sewage flow, also in US gallons,

or:

\[ V = 4260 + 0.75 \, Q \]

where

\( V \) is the net volume of the tank in litres, and \( Q \) is the daily sewage flow in litres.

3. For flows greater than 37 850 l (10 000 US gal.) per day, Imhoff tanks may be more satisfactory than septic tanks for primary treatment.

*Multi-compartment tanks*

Research by the US Public Health Service \(^3\) has demonstrated that properly designed, multi-compartment, household septic tanks give a performance as good as, or better than, single-compartment tanks of the same total capacity. This is especially true of the smaller tanks. As pointed out previously, the effects of fluctuations of flow and of surge flows are disastrous to the efficiency of the primary-treatment processes in small, single-chambered septic tanks. It is therefore desirable that small household tanks, i.e., those serving, say, less than 20-25 persons,
be provided with two compartments. The inlet compartment should have a capacity of one-half to two-thirds of the total tank capacity, and the liquid capacity of such an inlet compartment should be not less than 1900 l (500 US gal.) for the minimum installation. For the larger tanks, i.e., those serving more than 20-25 persons, the need for compartmenting the tank will depend upon the degree of treatment required by local health authorities and by the degree of permeability of the soil (where this applies). The research cited above shows that there is not much to be gained by an excessive number of partitions, and that a well-designed, single-chambered tank will result in a suspended solids removal efficiency of over 60%.

Outlet and inlet arrangements

Various outlet and inlet devices have been used in septic tanks. Recent experimental research indicates that the baffle system or the arrangements shown in Fig. 64 and 65 are quite satisfactory and offer simplicity and ease of installation. The depth of penetration of these devices into the tank's liquid is very important, as it influences the volumes of clear space and of sludge accumulation. The research cited above shows that for best results the outlet device should penetrate below the surface to a depth of 40% of the liquid depth. In the case of horizontal, cylindrical tanks, this figure should be reduced to 35%. The inlet baffle or tee should extend 30 cm (12 in.) below water level.

Both devices should permit free ventilation through the tank and through inlet and outlet pipes. They should extend at least 15 cm (6 in.) above the water line and leave at least 2.5 cm (1 in.) clearance below the tank's cover for ventilation purposes. Baffles are usually placed 20-30 cm (8-12 in.) away from the inlet and outlet pipes, whose ends are flush with the tank's walls.

The invert of the inlet pipe should be at an elevation not less than 2.5 cm (1 in.), preferably 7.5 cm (3 in.), above water level. Connexions between two compartments are best made by means of an ell whose lower end does not penetrate into the liquid at a depth lower than the outlet device.

Shape of tank

The shape of the tank is important inasmuch as it influences the velocity of flow through it, the depth of accumulation of sludge, and the presence or absence of stagnant corners. If the tank is too deep, the other dimensions will be small, and a direct current from inlet to outlet will occur, greatly shortening the retention period. If the tank is too shallow, however, the sludge-clear space will be too small, and the effective cross-section of the tank will be unduly reduced. When the width is too great, there will be dead pockets of appreciable size at the corners where little, if any,
water movement takes place. Finally, if the tank is too narrow, the velocity of flow will be so great as to interfere with efficient sedimentation. Research\textsuperscript{39} shows that “in a two-equal-compartment arrangement, there is no difference in performance between rectangular and cylindrical shapes, if equal solids storage capacities are provided”. Rectangular tanks should be designed with a length not less than two, but not more than three, times the width. The liquid depth should not be less than 1.2 m (4 ft), but not more than 1.7 m (5.5 ft) in the large tanks. Clearance above the water level is usually 30 cm (12 in.)

\textit{Location of tank}

The septic tank should be so located as to permit easy drainage from the dwelling and to the effluent disposal system. When the latter makes use of subsurface irrigation, the location of the tank should be such as to ensure that sufficient area is available for disposal of the effluent and that tile lines may be laid on a gentle slope and at a depth not exceeding 75 cm (30 in.) at any point.

Since periodic inspections are necessary, the tank should not be buried more than 30-45 cm (12-18 in.) below ground level. In any case, inspection manholes should be extended to reach ground level. Precautions should be taken to prevent the entrance of surface run-off into the tank.

Because of the possibility of leakage, especially around the inlet and outlet pipes, the tank should be located preferably downhill and at least 15 m (50 ft) away from wells and other sources of water supply.

\textit{Construction of tank}

Septic tank systems belong to the category of works which require for their construction the direct assistance and supervision of engineers, or at least of experienced construction foremen. No attempt will be made to describe here in detail the steps which should be observed in the actual construction of a tank in a rural community. The following information and data may, however, be useful to the engineer entrusted with the construction of these systems.

Tanks are usually built of concrete, a material which offers a guarantee of strength and imperviousness. Sometimes the bottom and the cover of the tank are made of concrete while the walls are built of bricks, cut-stone, or cement blocks laid with rich cement mortar and plastered (on the inside tank surface) with a 1 : 3 cement-sand mixture. A concrete mixture of 1 : 2 : 4 cement sand-gravel containing 23 l (6 US gal.) of water per bag of cement (94 pounds or 43 kg) should be used. Concrete walls and bottom should not be less than 10 cm (4 in.) thick, with adequate reinforcement.
The tank cover should be strong enough to withstand the weight of earth cover and occasional extra loads. Sectional slabs may be used where the tank is protected against surface water run-off. If not, the cover should be cast monolithically with the walls and raised manholes provided. For small tanks, one manhole placed above the inlet is sufficient. For large tanks, two manholes—one above the inlet and the other above the outlet—are necessary. The minimum size of the manholes should be 50 cm (20 in.) square or 61 cm (24 in.) in diameter.

The circular cover, although more difficult to build than the square or rectangular cover, is sometimes preferred as it cannot fall through the opening in the course of handling and tank-cleaning operations. In an area in India where filariasis was a serious public health problem, it was found that *Culex fatigans*, the local mosquito vector of the disease, was breeding in many septic tanks in households and institutions owing to the fact that the rectangular covers had fallen into the tanks through the manhole covers along their diagonal axis at the time of cleaning and had not been replaced.\(^a\)

Concrete septic tanks can be pre-cast either monolithically or in small parts at a central shop and erected quickly in the field. They are also made commercially of metal to which a special coating is applied to prevent corrosion.

**Operation and Maintenance of the Septic Tank**

As previously indicated, a newly built septic tank should first be filled with water up to outlet level and then should be seeded with several (5 to 8) buckets full of ripe sludge (or decomposing stable manure ripe enough to give off an ammonia odour).

Although the designs recommended provide for desludging about every two years or more, the tank should be inspected every 12-18 months in the case of household installations, and every six months in the case of tanks serving schools and other public institutions. The inspection should be directed towards the determination of:

(a) the distance from bottom of scum to bottom of outlet (scum-clear space) (see Fig. 64);

(b) the depth of accumulation of sludge over tank bottom.

The scum-clear space should not be less than 7.5 cm (3 in.), and the total depth of scum and sludge accumulations should not be more than 50 cm (20 in.).

Sludge may be bailed out by means of a long-handled, dipper-type bucket, or it may be pumped out by a specially equipped cesspool-emptying

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\(^a\) Personal communication from Dr T. R. Rao, Assistant Director of Public Health (Malaria), Bombay State, India
vehicle. Where large tanks are provided with bottom hoppers, cleaning is sometimes done by flushing and pushing the sludge out of the tank towards a drying bed by the hydrostatic head available in the tank. Even if care is taken, undigested sludge is likely to be removed also from the tank in this way. On the other hand, digested sludge is fairly dense and does not flow easily. This procedure is not recommended for application in rural areas.

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 fertilizer, but may be profitably composted along with other organic wastes (garbage, grass clippings, etc.). Otherwise, it should be buried in shallow, 60-cm- (2-ft-) deep, trenches. Provision should also be made for more frequent (perhaps every 3 to 6 months) inspections of the distribution box.

In a few instances, local health authorities may require that the effluent from septic tanks or disposal fields be disinfected before discharge into a small stream or public pond. This is especially true of hospital effluent, which is likely to contain live germs of transmissible diseases. Chlorine, as calcium hypochlorite, is commonly used for this purpose and is applied by means of hypochlorinators.

Because of the need for regular, intelligent care to ensure the proper operation of septic tank systems, it is desirable that some persons in the rural community be instructed in their maintenance and repair. Local health authorities should stimulate the formation of “co-operatives” or the setting-up of private concerns willing to undertake the maintenance work. These authorities should also stimulate requests from the people for advice on septic tank construction and maintenance and should be prepared to give technical guidance to all interested persons.

**THE DISPOSAL OF EFFLUENT**

The quality of septic-tank effluent and the biological processes involved in its purification have already been discussed. One conclusion to be drawn from this discussion is that septic-tank effluent should never be permitted to run in canals and open ditches, or to be disposed over land for the irrigation of crops or into small fishponds without the permission of local health authorities.

In rural areas and small communities, the choice of methods available for treating and disposing of the effluent is usually limited to (a) dilution, (b) seepage pits, (c) subsurface irrigation, (d) filter trenches, (e) sand filters, or (f) trickling filters.
In order to be able to select the method which is most appropriate to the particular location under consideration, it is necessary to determine the nature of the ground, the depth of the ground-water table, the degree of permeability of the soil, the proximity of wells and other water-supply sources, the volume and the rate of renewal of surface water available for dilution (in streams, ponds, and other bodies of water), and the uses made of this surface water (e.g., water supply, fishing, bathing). Among other factors to be considered are the land area available for the disposal works, the proximity of houses, the prevailing directions of the wind, the vegetation cover of the disposal land, and probable future extensions of the system.

The methods of disposal by dilution and by seepage pits have already been described in connexion with the disposal of raw sewage (see pp. 122-125).

**Disposal by Subsurface Irrigation**

This is the method most often employed in connexion with small septic tanks serving households and institutions. It consists simply of dispersing tank effluent into the top layer of the ground by means of open-jointed drain pipes laid in trenches and covered. In this way the effluent is purified through the action of the aerobic saprophytic bacteria of the soil and percolates away into the ground. It is obvious that this method cannot be used where the subsoil is not porous, where the ground-water table rises to within 1.2 m (4 ft) of the ground surface, or where there is the danger of pollution of water supplies (in fissured limestone formations, for example). In particular, it is not applicable in impervious clay soils and swampy lands.

**Percolation tests**

In order to calculate the length of pipe required in the disposal field, it is necessary to determine the degree of permeability of the soil by making percolation tests. The method for performing such tests has been recently improved as a result of numerous field investigations.\(^3\)\(^{39}\)\(^{40}\) The following is quoted from Part III of *Studies on household sewage disposal systems* : \(^{39}\)

**Percolation Test Procedure**

"Because of the great number of factors that may affect a percolation test and the variability that can be expected in the rate-time relationship, it appears unlikely that a short-time procedure can be developed, applicable to all soils and all conditions.

"It is thought best at this time to concentrate on developing a fundamental and objective test procedure which can be applied to a wide range of soils and which, as has been pointed out, would be essential in clay-type soils. Such a test would also be essential where no experience with test methods or a particular soil is available. As experience is gained, the test might be modified to suit local conditions. The fundamental test might also be used to check modified procedures from time to time."
"The following percolation test is suggested as a fundamental and objective procedure:

"1. Number and location of tests. — Six or more tests shall be made in separate test holes spaced uniformly over the proposed absorption field site.

"2. Type of test hole. — Dig or bore a hole, with horizontal dimensions of from 4 to 12 inches [10-30 cm] and vertical sides, to the depth of the proposed absorption trench. In order to save time, labor, and volume of water required per test, the holes can be bored with a 4-inch [10-cm] auger.

"3. Preparation of test hole. — Carefully scratch the bottom and sides of the hole with a knife blade or sharp pointed instrument, in order to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Remove all loose material from the hole. Add 2 inches [5 cm] of coarse sand or fine gravel to protect the bottom from scouring and sediment.

"4. Saturation and swelling of the soil. — Carefully fill the hole with clear water to a minimum depth of 12 inches [30 cm] over the gravel. By refilling if necessary, or by supplying a surplus reservoir of water, such as in an automatic siphon, keep water in the hole for at least 4 hours and preferably overnight. Allow the soil to swell overnight. This saturation procedure insures that the soil is given the opportunity to swell and approach the condition that it will be in during the wettest season of the year. Thus, the test will give comparable results in the same soil whether made in a dry or a wet season.

"In sandy soils containing little or no clay, the swelling procedure is not essential and the test may be made as described under item 5C, after the water from one filling of the hole has completely seeped away.

"5. Percolation rate measurement. — With the exception of sandy soils, percolation rate measurements shall be made on the day following the procedure described under item 4, above.

"A. If water remains in the test hole after the overnight swelling period, adjust the depth to approximately 6 inches [15 cm] over the gravel. From a fixed reference point, measure the drop in water level over a 30-minute period. This drop is used to calculate the percolation rate.

"B. If no water remains in the hole after the overnight swelling period, add clear water to bring the depth of water in the hole to approximately 6 inches [15 cm] over the gravel. From a fixed reference point, measure the drop in water level at approximately 30-minute intervals for 4 hours, refilling 6 inches [15 cm] over the gravel as necessary. The drop that occurs during the final 30-minute period is used to calculate the percolation rate. The drops during prior periods provide information for possible modification of the procedure to suit local circumstances.

"C. In sandy soils (or other soils in which the first 6 inches [15 cm] of water seeps away in less than 30 minutes, after the overnight swelling period) the time interval between measurements shall be taken as 10 minutes and the test run for 1 hour. The drop that occurs during the final 10 minutes is used to calculate the percolation rate.

"6. Additional criteria for judging soil suitability. — In areas of shallow ground water, the depth to the water table shall be determined. If, for any extended period during the year, the water table is normally at a depth of less than 4 feet [1.2 m], the results of the percolation test should be applied with caution. The case also warrants special consideration if impermeable layers are found at depths of less than 4 feet [1.2 m]."

The effective absorption area required may then be found from the Table X.
TABLE X. ABSORPTION-AREA REQUIREMENTS FOR RESIDENCES AND SCHOOLS *

<table>
<thead>
<tr>
<th>Percolation rate (time required for water to fall 2.5 cm (1 in.), minutes)</th>
<th>Required absorption area (square metres of absorption trench bottom per person served)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>residences</td>
</tr>
<tr>
<td>2 or less</td>
<td>2.30</td>
</tr>
<tr>
<td>3</td>
<td>2.80</td>
</tr>
<tr>
<td>4</td>
<td>3.25</td>
</tr>
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<td>5</td>
<td>3.50</td>
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<tr>
<td>10</td>
<td>4.65</td>
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<tr>
<td>15</td>
<td>5.35</td>
</tr>
<tr>
<td>30</td>
<td>7.00</td>
</tr>
<tr>
<td>45</td>
<td>8.45</td>
</tr>
<tr>
<td>60</td>
<td>9.30</td>
</tr>
<tr>
<td>Over 60</td>
<td>Unsuitable for shallow absorption system</td>
</tr>
</tbody>
</table>

* Adapted from table given in Studies on household sewage disposal systems. 29

As indicated by Table X, a percolation rate of 60 or more is an indication that the soil is unsuitable for effluent disposal by subsurface irrigation. In such a case, the possibility of constructing seepage pits which may penetrate into a deeper, permeable layer of the ground or the use of sand-filter trenches may be considered.

It may be emphasized that effective absorption area means the flat area in the bottom (only) of trenches. Attention is drawn to the fact that the figures given in the Table X are based on a daily flow of 190 l (50 US gal.) of sewage per person in residences. In many parts of the world, the daily flow of sewage will be found to be substantially less than this, in which cases the figures in the table might be reduced on the basis of actual field experience.

Construction and layout of disposal field

Distribution box

As its name implies, a distribution box is a chamber which ensures an even distribution of the effluent to the subsurface disposal field through the drain pipes (see Fig. 67). If easily accessible, it may also serve as an inspection manhole for checking the amount of suspended matter in the effluent from the septic tank as well as the proper distribution of effluent. It requires care in its design and construction; and, for efficient operation —i.e., the equal distribution of flow among its various outlets—occasional inspection and maintenance are needed. Experience shows that an outlet may become partially obstructed by floating matter from the septic tank,
if the latter needs cleaning, or by other solid matter (twigs, small stones, etc.), which may have fallen accidentally through the manhole. As a result, a portion of the disposal field may be inoperative and the rest overloaded, becoming “sewage sick” within a short time.

**FIG. 67. TYPES OF DISTRIBUTION BOX**

Adapted, by permission, from *Manual of septic-tank practice.*

A = Baffle in wood or brick  
B = Inlet from septic tank or dosing chamber  
C = Outlet to absorption lines

The general practice followed in the design of distribution boxes may be described as follows:

1. The inlet pipe should enter at one end of the box about 2 inches [5 cm] above the bottom. Sides of the box should extend approximately 12 inches [30 cm] above the invert of the inlet pipe and the box should be provided with a removable cover. Since frequent inspection is not necessary, the cover of the box may be placed 12 to 18 inches [30 to 46 cm] below the surface of the ground. Drainage lines should be constructed with
inverts at bottom level of the box or approximately one inch [2.5 cm] above the bottom and all should be set at the same elevation. They should run straight in the desired direction. Horizontal bends should be avoided where possible; when necessary, however, they should be made with tight joints. When set at the same elevation and operating under the same head, pipes all of the same size are more likely to receive an equal flow. Lines may be run from an elevation several inches above the bottom of the box, but care must be taken to insure that all lines leave the box at the same elevation.

"The box need not be more than 18 inches [46 cm] in width, nor longer than is necessary to accommodate drains for effective outlet capacity. Diversion baffle boards should not be installed in distribution boxes on systems serving individual dwellings. However, such construction may prove advisable on systems serving public buildings where constant supervision and maintenance are provided and where the purpose of such baffle boards may be realized. Lines may be shut off at will for repairs or to rest the field when it comes waterlogged, provided a distribution box is installed. Flow diversion devices may be installed in the properly designed distribution box to facilitate rotation of use of the distribution lines where adequate and proper maintenance is assured."

**Pipes and trenches for septic-tank effluent**

Plain-end tile pipes, 10 cm (4 in.) in diameter and 30-60 cm (12-24 in.) in length, are commonly used (see Fig. 67). Bell and spigot sewer pipe of the same diameter but 61 cm (2 ft) in maximum length may be preferred. A small stone or cement fillet may be used in the bottom of each socket.

**FIG. 68. ABSORPTION TRENCHES**

A = Coarse gravel surrounding pipe  
B = Bell and spigot pipe  
C = Building or tar paper  
D = Wooden stakes supporting grade board E  
E = Longitudinal boards, nailed to stakes and laid at exact grade selected for absorption lines  
F = Absorption tile pipes resting over grade boards  
G = Tar paper covering upper half of open joints  
H = Earth-tamped backfill
joint to centre the spigot in the bell. Plain-end tiles need a firm support to remain on an even grade and, hence, to effect uniform distribution of the septic-tank effluent. Such a support is provided by means of a flat board—for example, $2.5 \times 10$ cm ($1 \times 4$ in.) in size—which is set on edge and nailed to stakes driven at intervals in the bottom of the trench. The top of the board can be laid accurately to the desired grade (see Fig. 68).

Both types of pipe are laid in such a way as to leave an open space of 0.6-1.2 cm (0.25-0.50 in.) between pipe lengths for the effluent to run out. When plain-end pipes are used, the upper half of the joint must be covered with a strip of asphalt or tar paper to prevent entrance of fine sand and silt which might interfere with the flow of effluent. Ball and spigot pipes do not require this protection, since the joints are protected by the bell ends. In either case, however, the joints should be covered with at least 5 cm (2 in.) of gravel. Some authors even recommend that irrigation trenches be filled to the ground surface with filter material (gravel), thereby reducing the risk of silt’s entering the drain. The portion of the effluent drain located between the septic tank and the distribution box and a length of, for example, 1.50 m (5 ft) of outlet line from the distribution box should be laid with tight cement joints.

The depth of pipe-inverts should not by less than 30 cm (12 in.) nor more than 75 cm (30 in.). An earth cover of about 30 cm (12 in.) is desirable to protect the pipe against injury. Under roads, or paths followed by heavy agricultural machines, it may be necessary to use cast-iron pipes or strong vitrified sewer-pipes, laid with tight joints, in order to maintain line and grade.

The grade of the disposal pipelines should not be too small or too great; if too flat, only the upper area of the disposal field will receive the effluent; if too steep, there will be a rush of liquid in the upper portion of the pipelines towards the lower portion of the disposal field, which will soon be waterlogged. Experience dictates a slope of 0.16% to 0.32%—i.e., 2-4 in. per 100 ft—with a maximum of 0.5%. In order to maintain such grades on steep-sloping lands, disposal pipes should be laid along the contours of the ground, and changes of direction should be made by means of drop-boxes or terracotta L’s laid with cemented joints. At such points special precautions should be taken to cut off the underground flow of sewage which is normally running above the upstream trench bottom and which may cause erosion of the ground around the drop-boxes and terracotta L’s. This may be done by filling with well-tamped clay soil the last 30 cm (12 in.) of trench preceding each drop-box or L-pipe.

The size and lengths of trenches required should be calculated on the basis of the figure previously obtained for effective absorption area. The size and minimum spacings recommended may be obtained from the Table XI.
TABLE XI. SIZE AND MINIMUM SPACING REQUIREMENTS FOR DISPOSAL TRENCHES

<table>
<thead>
<tr>
<th>Width of trench at bottom (inches)</th>
<th>Depth of trench (inches)</th>
<th>Effective absorption area (sq. ft/ft)</th>
<th>Spacing of tile lines * (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>18 to 30</td>
<td>1.5</td>
<td>6.0</td>
</tr>
<tr>
<td>24</td>
<td>18 to 30</td>
<td>2.0</td>
<td>6.0</td>
</tr>
<tr>
<td>30</td>
<td>18 to 36</td>
<td>2.5</td>
<td>7.5</td>
</tr>
<tr>
<td>36</td>
<td>24 to 36</td>
<td>3.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

* A greater spacing is desirable where available area permits.

Trenches should not be too long; otherwise, the effluent will not be evenly distributed over the disposal field. No trench should be longer than 30 m (100 ft). The smallest household disposal system will consist of two trenches 45 cm (18 in.) wide at the bottom and 30 m (100 ft) long, irrespective of calculated findings.

So far as possible, trenches should be laid along straight lines. The herringbone type of layout is no longer used since Y-branches do not, in actual practice, ensure even distribution of the effluent over the disposal field. Parallel lines issuing individually from a common distribution box are now preferred.

After the trenches are dug to the required size and depth, a layer of 15 cm (6 in.) or more of filter material is placed over the bottom. The pipes are then laid to the required grade, as previously described, and are surrounded by more filter material, at least 5 cm (2 in.) thick above the top of the pipe. The rest of the trench is then backfilled with earth. The filter material may be washed gravel, crushed stone, slag, or clean clinker ranging in size from 1.2 cm to 6 cm (0.5 in. to 2.5 in.), although one single size (e.g., 1, 1.5, 2, or 2.5 in.) is sometimes preferred.71

Surface run-off should, of course, be diverted away from the disposal field in order to avoid waterlogging of the soil, especially at times of heavy rains.

Finally, trenches should be laid at least 7.5 m (25 ft) away from large trees to avoid blockages due to the penetration of roots into the pipes. For the same reason, the land area above the disposal field should not be cultivated, but may be planted with short-rooted grass.

**Seepage pits**

Depending upon the layout of the trenches, it is good practice to build one or more seepage pits at the lower ends of the absorption lines, as this serves to catch excess effluent and, possibly, to ventilate the trenches through the piping system. The last 1.5 m (5 ft) of trench preceding the
seepage pit should be filled with well-tamped clay soil in order to stop the flow of sewage above the trench bottom and to prevent erosion.

**Pipes and trenches for aqua privies**

Subsurface irrigation is also convenient for the disposal of the effluent from aqua privies. The principles of design, the size and types of pipes used, and the width of trench recommended are the same as above indicated. However, the essential difference rests in the fact that the volume of aqua-privy effluent is much smaller than that of septic tanks. As a result, the length and grade to be given to trenches and pipes will differ from those recommended for the disposal of septic-tank effluent. The required length of trench may be calculated from Table XII, which is adapted from figures suggested by Macdonald.  

**TABLE XII. REQUIRED ABSORPTION AREAS FOR AQUA PRIVIES**

| Percolation rate (time required for water to fall 2.5 cm (1 in.), minutes) | Required absorption area (square metres of absorption trench bottom) for aqua privies serving: |
|---|---|---|---|
| | 10 persons | 25 persons | 60 persons |
| 2 or less | 2.80 | 5.60 | 9.80 |
| 5 | 3.75 | 7.00 | 11.70 |
| 10 | 4.65 | 9.80 | 16.20 |
| 15 | 6.00 | 11.70 | 19.50 |
| 30 | 8.00 | 16.70 | 25.00 |
| 45 | 9.00 | 18.00 | 30.80 |
| 60 | 10.25 | 19.50 | 33.50 |

For absorption areas less than 7 m² (75 sq. ft), trenches may be 30 cm (12 in.) wide at the bottom; other trenches should have a bottom width of 45 cm (18 in.). A minimum slope of 1% is recommended.

**Dosing Siphons**

The importance of the penetration of air into the pores of the subsoil has been previously stressed (p. 129). In order to enable the soil to recover between doses of effluent and to obtain uniform distribution of sewage through the entire distribution line, a dosing chamber equipped with one automatic siphon is recommended for a large septic tank, i.e., one of more than 3785-1 (1000-US-gal.) capacity. For tanks having a capacity exceeding 7570-9463 l (2000-2500 US gal.), a dosing chamber equipped with two
siphons is recommended. These siphons will operate alternately, and each will serve half the distribution field. The dosing chambers are usually installed at the outlet of septic tanks, and receive the effluent which accumulates over a calculated period of 2-3 hours before being discharged into the disposal field. (See Fig. 65 and 69.) The effective capacity of these chambers is equivalent to the volume of water required to fill all the disposal pipes from one-half to three-quarters full at one time.

**FIG. 69. TYPICAL DOSING SIPHON**

![](image)

A = Miller siphon  
B = Diameter of siphon, dependent upon population served  
C = Maximum drawing depth of water in dosing chamber  
D = Discharge to distribution box and absorption lines  
E = Overflow pipe

The discharge capacity of the siphon should be less than the capacity of the disposal line leading from it to the subsurface irrigation field. A 10-cm (4-in.) siphon may be used for plants serving 20-40 persons, and a 12.5-cm (5-in.) siphon for those serving up to 100 persons.

Dosing siphons are particularly useful on systems involving sand-filter trenches and sand and trickling filters. They are not usually recommended for small, household types of installations, because of their cost.

**Sand-Filter Trenches**

Sand-filter trenches may be built in soils which are tight and impervious (clayey soils) and which have a percolation factor exceeding 60. They may also be considered for installation in places where ground water
occasionally rises and reaches a level 90 cm (3 ft) below the ground surface, or when the area available for subsurface irrigation is too small for this purpose.

As shown in Fig. 70, a sand-filter trench is wider than a regular absorption trench and includes:

1. an effluent distributing pipe, usually 10 cm (4 in.) in diameter;
2. a sand-filter bed not less than 60 cm (24 in.) deep, preferably 75 cm (30 in.), through which the septic-tank effluent percolates and undergoes biological filtration;
3. an underdrain, also 10 cm (4 in.) in diameter, surrounded by a layer of gravel laid in the bottom of the trench. This underdrain receives the filtered effluent and discharges it into a ditch or similar watercourse. It also prevents the ground water from interfering with the biological processes taking place in the sand bed mentioned above.

Special care will be needed to ensure that the effluent-distributing pipes are laid on a uniform grade. When grade boards are not used, the sand bed should be flooded to ensure thorough settlement before the distribution pipes are laid.

Clean, coarse sand should be used as filtering material, as fine sand will be quickly clogged and will lead to failure of the system.

The distribution piping and the underdrains may be built of the same pipes as are used for the construction of the standard absorption trenches already described, i.e., plain-end tile pipes or bell and spigot sewer pipes. Long, perforated pipes have the advantage of maintaining the desired grade, and may be preferred for use in the distribution of septic-tank effluent over the sand bed. The slope of the effluent distribution pipes may be the same as that previously mentioned for standard absorption trenches, while the slope of underdrains may be as much as 1%.

The loading rate for sand-filter trenches is estimated at about 38 l per m² (1 US gal. per sq. ft) per day of filter surface.
Sand-filter trenches usually produce a highly purified effluent which may be disposed of in open ditches or streams. There is, however, no certainty that the filtered effluent is bacteriologically safe. When the receiving stream is used as a source for domestic water-supply, the effluent should be chlorinated. In any case, sand-filter trenches should never be constructed without the prior approval of the local health department.

**Sand Filters**

**Subsurface sand filters**

Subsurface sand filters operate under the same principles as sand-filter trenches. They “constitute a maximal artificial development of the filtering capacity of the subsurface [soil]”.\(^{13}\) The area required for filtration, as found by the engineering design, is dug up to the required depth and is filled in artificially with coarse sand, after the effluent distribution pipes and the underdrains have been placed. (See Fig. 71.) The loading rate for subsurface sand filters and the pipes used are the same as those mentioned above for sand-filter trenches. Their effluents compare favourably with the effluents from filter trenches and may be disposed of in the same manner.

For large installations, subsurface sand filters are likely to be cheaper than filter trenches and should be selected over the trench system when dosing siphons must be installed. Siphons have the advantage of ensuring adequate dosage and of providing a long rest-period for the filter sand. Dosing tanks equipped with single siphons should be installed where the total filter area exceeds 17 m\(^2\) (1800 sq. ft) and where the distribution pipes exceed 90 m (300 ft). When the length of these pipes is greater than 245 m (800 ft), the filter bed should be divided into two or more sections and dosed separately by alternating siphons.\(^{33}\) Lining of the bed (or beds) is not necessary except in very wet, soft soil.

Subsurface sand filters, like sand-filter trenches, may be built in most rural areas of the world. They require no attention. However, since they cannot be maintained, they eventually become clogged and must be rebuilt.

**Open sand filters**

In areas where the ground water remains permanently close to the ground surface, or where subsoil conditions are unfavourable (e.g., rock formations) for the construction of disposal systems already described, open sand filters may be considered. These filters are built above ground or partly below ground as the local circumstances dictate. In both instances, masonry or concrete walls are needed to support the sides and to retain the sand. Earth embankments may also be used for the same purpose.
FIG. 71. SUBSURFACE SAND FILTER

Section:
A = Coarse-gravel or crushed stone
B = Underdrain for collection of filtered effluent
C = Coarse filter sand
D = Coarse gravel or crushed stone
E = Effluent distributing pipes made of tiles or of perforated pipes
F = Backfill, tamped in moist layers 15 cm (6 in.) thick
G = Top soil
H = Original ground-level
I = End line of subsurface filter

Plan:
I = Septic tank
II = Discharge line
III = Siphon chamber
IV = Distribution boxes
V = Effluent distributing pipes (= E in section)
VI = Underdrain for collection of filtered effluent (= B in section)
VII = Collection pipe to final point
VIII = Limits of subsurface filter

Measurements shown are in centimetres.
In open sand filters, purification of the septic-tank effluent is due to the action of aerobic bacteria in the interstices of the sand bed and to mechanical straining. Since these bacteria require oxygen in order to survive, the filters are usually operated intermittently so that air is drawn into the filter bed during the intervals between dosing. For this reason, these filters are frequently referred to as intermittent sand filters. If properly constructed and operated, open sand filters produce an effluent of high and stable quality.

FIG. 72. OPEN SAND FILTER

Adapted, by permission, from Manual of septic-tank practice.37

A = Cast-iron pipe lines from dosing chamber
B = Control valves, allowing for cleaning and repairs of filter beds without interrupting operation
C = Concrete splash slabs; top surfaces are left in rough state
D = Underdrains, laid 1.8 m (6 ft) or more apart, with open joints to receive filtered effluent
E = Collector to disposal. Pipes laid with tight joints
F = Coarse gravel or crushed stone
G = Coarse filter sand, 75-106 cm (30-42 in.) thick
H = Original ground-level

Open sand filters are usually divided into two or more compartments in order to facilitate regular cleaning of the beds and to regulate operation (see Fig. 72). As in the case of subsurface sand filters and of filter trenches,
a bed of clean coarse sand 75-105 cm (30-42 in.) thick, underlaid with gravel will be used. Sand material possessing an effective size of 0.2-0.4 mm and a uniformity coefficient of 4.0 will give satisfactory performance. (By effective size is meant the size of the sand particle that is coarser than 10% by weight of the material. The uniformity coefficient is found by determining the size of the particle that is coarser than 60% by weight of the material and by dividing that size by the effective size.)

In small installations, the underdrainage system and the effluent distribution pipes may be arranged in the manner shown in Fig. 72. The larger systems are built and operated on the principles of municipal sand filters.

The loading rates for open sand filters are greater than those allowed for subsurface sand filters. They depend primarily upon the degree of treatment achieved in the septic tanks, the size of the sand particles used, and, also, the temperature. Loading rates applicable in warm climates are higher than those allowable in temperate and northern countries. As an example, the loading rates on open sand filters with uniformity coefficients not over 4.0 recommended for application in the USA are as follows, in litres per m² per day:

<table>
<thead>
<tr>
<th>Region</th>
<th>Effective size of sand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.2 mm</td>
</tr>
<tr>
<td>Southern USA</td>
<td></td>
</tr>
<tr>
<td>Northern USA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>378 000</td>
</tr>
<tr>
<td></td>
<td>300 000</td>
</tr>
</tbody>
</table>

The intermittent operation of open sand-filter beds is usually achieved by the use of dosing siphons. Depending upon the volume of sewage to be treated, these siphons are operated in such a manner as to supply one dose per day or a single dose in several days. Most commonly one to four doses per day are provided, the bed being covered each time to a depth of 5-8 cm (2-3 in.). The best practice calls for the installation in the same chamber of two siphons operating alternately and discharging upon different beds.

Open sand filters need not be covered in most instances. However, in order to prevent odours and nuisances which may arise when operation is deficient, or to avoid freezing in northern climates, it may be necessary to cover the beds of sand with a layer of 15 cm (6 in.) of earth.

The great disadvantage of these filters lies in the fact that they require considerable attention. Constant maintenance and cleaning of the sand surface are required; otherwise, the ventilation of the beds is interrupted, and the nitrifying bacteria die away. Cleaning is done by raking the beds and, when necessary, by removing the top 2.5 cm (1 in.) of dirty sand. This sand is washed and returned to the bed in order to maintain the depth of the filter bed.
Because of the care needed in their construction and, especially, in their operation, open sand filters are recommended only for use in communities which can afford the services of competent sanitary engineers and sewage-plant operators. The advice and approval of the local health department should be sought prior to their construction.

**Trickling Filters**

Trickling filters, also called percolating filters, are used as a means of secondary treatment of septic tank effluent in the more economically favoured rural areas, where sanitary engineering advice may be obtained for the construction and operation of such units. In this method the effluent is trickled intermittently through a thick bed of crushed stone, metallurgical coke, lath, or even brush (twigs cleaned of leaves and bound in bundles). (See Fig. 73.)

The rate of application of sewage to small installations is governed by the volume and strength of the sewage to be treated. In the USA the rates recommended range from 175,000 US gal. to 225,000 US gal. per acre per day for each foot of depth of bed \(^{20}\) (i.e., 558 l to 718 l per m\(^3\) of filter medium). In the United Kingdom of Great Britain and Northern Ireland, where the domestic sewage is usually stronger than in the USA due to a smaller per person consumption of water, a figure of 45 Imp. gal. per cubic yard of filter bed (268 l per m\(^3\) of filter bed) is recommended for design purposes by the Royal Commission on Sewage Disposal.

The depth of a trickling filter bed usually varies from 2 m to 3 m (6 ft to 10 ft). The bed should consist of clean, durable material of the quality mentioned above, and the stones should have angular shape and rough surfaces. In such a filter, air must circulate freely in order to maintain the zoogloeoal flora which thrive over the stones in the presence of oxygen. The larger stones, 8-10 cm (3-4 in.) in size, will form a layer 15-20 cm (6-8 in.) thick at the bottom of the bed; the smaller stones (not less than 2.5 cm or 1 in. in size) will make up the filter bed.

In small trickling filters, distribution of the septic-tank effluent over the bed is accomplished by means of static distributors fed intermittently by a tip trough or a dosing siphon (see Fig. 73). The tip trough allows admission of the sewage to half of the bed at a time. It is usually not more than 4.20 m (14 ft) in length and serves a filter area not more than 1.50 m (5 ft) wide on either side of the trough. Trickling filters larger than this require additional tip troughs. However, the latter should not be used when the bed exceeds 47 m\(^2\) (500 sq. ft) in area.\(^{80}\)

The distributors may be made of cast iron, concrete, or plain 2.5 × 7.5 cm (1 × 3 in.) boards. Cast iron and concrete distributors often assume the shape of channels whose bottoms are perforated with small holes, or
FIG. 73. SMALL TRICKLING FILTER

A = Inlet
B = Outlet
C = Two-way tipper
D = Air-vent
E = Aeration tiles
F = 6-in. (15-cm), half-round, aeration tiles
G = T-iron support
H = Distribution channel with serrated sides
I = 1-in. to 1/2-in. (2.5-3.8-cm) graded media
J = 3-in. to 4-in. (7.5-10-cm) graded media
whose sides are notched at close intervals in order to let the sewage out in the form of rivulets above the bed.

Trickling filter units should be constructed of concrete or other suitable materials and should be located at least 45 m (150 ft) away from human habitations. Such filters are usually uncovered and are likely to produce odours. Also, they breed large numbers of a small, moth-like fly of the genus *Psychoda*, which may be carried away by the wind into human habitations. *Psychoda* flies do not bite but are a serious nuisance to man. They are controlled by operating the filters for a while at a very high rate of filtration, thus reducing by sloughing the thickness of the zoogloea film in which the fly larvae develop. Chlorinated lime may also be applied once a week to the bed with similar results.

The effluent of trickling filters normally contains humus-like materials which, in large installations, are removed by passing the effluent through a secondary settling tank. In small systems serving, for example, less than 100 persons and where the effluent can be disposed of without nuisance or danger to sources of domestic water-supply, humus tanks are usually not provided. When needed, such tanks should have a detention period of four hours and be designed like a septic tank, except for the cover. The floors of these tanks are designed to slope down to a sump at the inlet end to permit periodic removal of sludge by scoops or by pumps.
EXCRETA DISPOSAL PROGRAMMES
FOR RURAL AREAS

THE PLANNING OF EXCRETA DISPOSAL PROGRAMMES

Essential Elements

In planning an excreta disposal programme for rural areas, it is important to remember that such a scheme should be considered only as a part of a general sanitation plan for the country concerned. An excreta disposal programme is not an end in itself and, even if successful, cannot be expected, alone, to produce a considerable reduction in morbidity and mortality due to enteric infections. Often a long-range plan of general sanitation does not exist either because there are still doubts among health officials as to the benefits of sanitation, or because these officials do not have the knowledge and the desire to face the sanitation problem, which in many countries assumes staggering proportions.

As a result of experience acquired in many parts of the world, Baity a has suggested that the governments concerned might take the following progressive steps:

1. Recognize the real benefits of sanitation to the health and well-being of their people.
2. Establish a sanitation unit within the national health service of the country, commensurate with the country’s needs and resources, and staff it with personnel competent to plan and direct all phases of work in this field.
3. Integrate sanitation properly with other public health undertakings, and see that “first things come first” in the assignment of priorities.
4. Develop a long-range plan of sanitation for the country as a whole, into which projects and programmes may be logically fitted as to time and place.
5. Realize that it is possible to do something helpful in environmental sanitation under any conditions and under any budget—and that the simplest things are usually the most important.
6. Select a point of beginning, always the most difficult step in such an undertaking, and outline an orderly progression of work and objectives.

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a Baity, H. G. (1956) The sanitary sceptics—Shall we condemn them or teach them? (Unpublished working document WHO/Env.San./93)
In most countries of the world the disposal of human wastes should constitute an important part of any long-range plan for sanitation development and might well be a desirable starting-point for such an undertaking. Once a decision has been made as to the proper time and place for an excreta disposal programme, the following elements might be considered in planning:

(a) preparation of necessary staff;
(b) initiation of a community sanitary survey;
(c) selection of the type, or types, of units to be built;
(d) study of the possibility of a pilot project in the area under consideration;
(e) estimate of costs;
(f) health education of the population;
(g) programme and schedule of construction;
(h) maintenance of the installations;
(i) appraisal of results and promotion of further sanitation development; and
(j) establishment of sanitary regulations.

Preparation of Staff

The planning and execution of any programme of environmental sanitation require the services of technically qualified professional and non-professional staff. This is particularly true in the case of excreta disposal programmes for rural areas and small communities. It is desirable that in every country specialists in environmental sanitation be placed at an appropriate level within the health administration and that they be made responsible for the formulation and development of programmes relating to their competence. One of their functions should be to undertake, in co-operation with medical and other health personnel, a close study of the status of rural sanitation and the staff required for its improvement. Such a study would be expected to provide the facts on which a programme, however simple, could be based, and to lead to decisions as to the means whereby it could be implemented. The assistance of these specialists should be made available to local health services when necessary for the solution of difficult problems.

At the local (or district) level, there will be a need for well-trained public health (or sanitary) inspectors, who will be directly in charge of the execution of the programme. These officers will be assisted by a number of health assistants and health aides posted in rural towns and
villages. The possibility of organizing village-level workers on a voluntary basis may also be considered as a part of a self-help movement within each community.

In rural excreta disposal programmes, the quality and quantity of the sanitation work performed are directly related to the quality of the supervising personnel. It is therefore important to give considerable attention, before a programme starts, to the proper training of the sanitation staff which will carry it out. This applies particularly to the health assistants and health aides, who will be in closest daily contact with the population. The training scheme should be founded on a careful analysis of the functions to be performed by such staff. This matter will be studied further in the next chapter.

Community Sanitary Surveys

In most rural areas, community sanitary surveys are usually necessary to obtain first-hand information concerning local sanitary conditions and needs. Such surveys, undertaken with the participation of local leaders of the community, will be of immense help in programme planning and evaluation. Depending upon the particular situation at hand, they may cover the following factors in part or in whole.

A. Description of area

(1) location, topography, climate, character, communications, maps;
(2) geology and hydrology, with particular reference to nature of top and underground layers of the soil, its porosity, presence and abundance of ground water (if any), direction of flow, level of ground-water table, its appearance and potability, estimation of yields of springs, rivers, and so on;
(3) population—number, constitution by age-groups and sex, density, growth;
(4) industries and agriculture, with particular reference to irrigation, drainage, and soil fertilizing practices;

B. Medical and sanitary data

(1) general health of the population, with special emphasis on communicable diseases and on intestinal infections, helminth infestations, and trachoma and acute conjunctivitis in infants and children;
(2) vital statistics, mortality and morbidity data;
(3) health and sanitary administration, with reference to organization, personnel, budget, and activities of voluntary or other agencies in the field of sanitation;
(4) existing sanitary conditions in the area, with reference to description of private and public latrines, their distribution and use; to wells, springs, and other systems of water supply (including such information as number of persons served by piped water-supplies, and by wells, the consumption and uses of water, number of dwellings with private water supply, etc); to wastes collection, disposal, and composting; to milk and food sanitation; to insects (flies, fleas, lice, mosquitos); to health aspects and standards of housing; and to school sanitation.

(5) sociological and cultural patterns, with particular reference to community and family organization, leadership; customs, beliefs, and habits bearing on personal hygiene and community sanitation; present methods (if any) of health education of the public.

C. Resources available

(1) general economic level of the population; average income per caput;

(2) co-operation expected from agricultural, educational, and other agencies or groups for training and health education of the public;

(3) housing and vehicle transport for programme, vehicle and equipment repair and maintenance facilities; sources of power (electricity, fuel);

(4) local construction materials and their costs;

(5) local craftsmen and wages;

(6) potential resources for self-help.

This information has an important bearing on the project and makes it possible to draft a reasonably accurate cost estimate. Such a survey is a useful educational tool and also serves to acquaint the sanitation personnel with the families and with their customs, beliefs, interests, and attitudes. In short, it helps to prepare a "social map" of the community.

Health Education of the Population

In all programmes involving the disposal of human wastes, especially those undertaken in a rural environment, health education plays a most important role and should be one of the earliest considerations. It is through a well-planned and active programme of health education that health authorities will be able to secure the understanding, support, and participation of the rural population. This fact, which has already been discussed, cannot be overstressed.
Broadly speaking, the purposes of the educational programme should be:

(a) to create a desire for the improvement of excretory habits, or more generally, to create interest in, and awareness of, health problems which may be solved through improvement of personal, family, and community sanitation practices;

(b) to help people determine what changes are needed and desirable for improving sanitation and how they can be implemented;

(c) to encourage people to put into practice good habits of personal hygiene, as well as those measures which will serve to improve personal, home, and community sanitary conditions;

(d) to foster those learning experiences which would feature the people's participation and self-help in solving sanitation and related health problems;

(e) to provide instruction in the designs, materials, and methods involved in building and maintaining proper installations;

(f) to secure sustained interest and participation in a community programme of environmental health improvement.

In carrying out such a programme in rural areas and small communities, it is desirable to utilize to the fullest extent the assistance of the available local, provincial, and national personnel with skills and experience in family and group education methods, organization of village committees and councils, conduct of training courses for village leaders and school groups, and production and use of simple teaching aids and visual materials. In some countries there may be one or more persons with full or partial training in health education of the public. There may also be experienced leaders in adult education, rural development work, social work, rural education, religious leadership, agricultural extension work, and others whose collaboration should be sought and who may prove to be of considerable help to the sanitation personnel in planning and carrying out educational activities with family, school, and village groups.

**Selection and Design of the Units**

These subjects have already been covered in the previous sections. However, it might be worth while to reiterate here the fact that the choice of installation must be made in the light of: (1) what the community needs and is prepared to accept; (2) what the community can afford, giving due consideration to basic health criteria (p. 39); and (3) what the community can maintain in the future. The word that should describe
the design chosen is soundness. It does not mean luxurious or poor, expensive or cheap. It does mean the best possible installation at a cost which the particular community can afford.

The selection of units has a direct bearing on the success or failure of the excreta disposal programme. From the beginning, the technical aspects of the scheme must provide for a certain degree of flexibility because, once the programme is organized and started around a single type of installation, it is difficult to switch to another type and to “sell” it to the people.

**Pilot Projects**

When it is not possible, from the findings of the sanitary survey, to arrive at a safe conclusion regarding the type or types of units, their costs, and the construction procedure to be used, a pilot project should be carried out first. This method offers the quickest and most economical way of discovering the answers to these questions. Pilot projects are often desirable and may be undertaken especially in conjunction with the training of the sanitation personnel which will ultimately be employed in the programme. The use of such projects for demonstration purposes has also proved to be valuable in many countries in “selling” the programme to the people concerned.

**The Estimate of Cost and Budget**

It is quite possible that rural sanitation work has often failed because of inadequate cost estimates and budget. It is, indeed, exceedingly difficult to prepare cost estimates for projects that are new and drawn up mostly from unreliable information. The estimate of cost should be true, honest, and correct. If the basic data are poor, this should be made abundantly clear to those officials who will decide on budget matters. Health administrators throughout the world are predominantly medical people who cannot be expected to understand in detail the engineering phases of construction work. They are often confused when a project runs out of funds long before completion, and this may shake their confidence in the whole sanitation programme. To avoid this situation, it is important that every effort be made to prepare the best possible estimates of cost, based on complete field information and making generous allowances for unknown factors. The total sum required may appear staggering when all the figures are added up, but it is much better in the long run to accept the more difficult job of promoting a rural sanitation project that seems to be expensive beforehand than to try to justify a budget increase halfway through.
Construction

On the basis of data gathered in the course of the community sanitary survey, a decision should first be made whether construction will be carried out (1) by a well-organized campaign conducted by the health department, (2) by the family with guidance only from the sanitary (public health) inspector, or (3) by a combination of these two methods, involving the aid of the health department and the participation of the family in the form of labour or materials, or both. As pointed out before, the third method yields by far the best and longest-lasting results. If method 1 or 3 is decided upon, it should be possible to draw up a fairly detailed programme of construction of the projected facilities.

The programme of construction would indicate such things as the rural districts which should be tackled first; the proposed schedule of construction; the distribution and organization of construction gangs; the list and plan of utilization of available construction materials (donated or otherwise), equipment, and transport; and the organization and location of field warehouses and shops, etc. The construction programme should be flexible enough, however, to cope with unforeseen difficulties, such as those which may be created by unstable ground formations, high groundwater level, or low permeability of soils.

Experience shows that in the early stages progress will be slow, even though the units selected may be easy to build. Construction will then pick up momentum and go through a period of major activity until 75%-80% of the units are completed. Then it will again slow down.

Depending upon circumstances, resistance of certain groups to the excreta disposal programme may be anticipated; this should be taken into account in drawing up or revising the construction schedule.

Maintenance of Installations

When the tempo of construction slows down following the installation of most of the units projected, attention may be shifted to another rural district or community. The permanent staff member (sanitary inspector or health assistant) should pick up the work from there with whatever help may be needed from his immediate supervisor. He should continue his efforts to persuade the last persons still holding out to build sanitary installations and should undertake periodic visits to the homes where units have been built to ensure that these are properly used and maintained. Inspection and maintenance are necessary, since neglected installations may lose much of their value and may even constitute potential hazards to the community they are intended to serve. Provision should be made, right at the planning stage, for regular follow-up by sanitation personnel permanently stationed in the area.
Appraisal of Results
and Promotion of Further Sanitation Development

In planning a programme of rural sanitation, it is desirable to keep
in mind the need for an evaluation of results upon the completion of
construction activities or at a later date. The medical and sanitary data
collected in the course of the pre-operative sanitary survey of the area
should, if adequate and sufficiently reliable, provide a good basis for an
objective appraisal of the results of the programme. In some cases it
may be necessary to select for comparison purposes another area, similar
in character, in which comparable sanitation work is not being carried
out. This comparison area should be surveyed in the same manner and,
as far as possible, at the same time.

Measurements of the results may be by either direct or indirect means.
Direct measures, which are to be preferred when applicable, involve the
analysis of death-rates of specific age-groups of the population or the
study of morbidity returns and the results of special morbidity surveys.
Data on infant mortality due to specific diarrhoeal diseases are often
selected for studying the present status of sanitary conditions in an area.
However, Macdonald * states that death-rates for the ages 1 to 15 years
are a most delicate index of the amount of infective diseases in the popu-
lation and are the first to respond to sanitation programmes. He also
found that the range in death-rates for the age-group 1 to 4 is particularly
sensitive and less influenced by standards of maternal and child care and
public education. On the other hand, crude death-rates are generally
unreliable and may not reflect a successful rural sanitation programme
at all.

The study of morbidity returns may often lead to fallacious conclusions
since, depending upon local conditions, such returns may be influenced
by several factors, among which are inadequate records of notifiable
diseases, standards of diagnosis, and others. Objective measurements by
special morbidity surveys covering the faecal-borne diseases are very
desirable. Particular attention should be paid to prevalence of these
diseases in infancy and childhood.

Indirect measures involve observations of changes in the environment
which may indicate that rural health must have been improved as a result
of the sanitation programme. They do not provide direct evidence of
health improvement; for this reason they are less desirable from a technical
standpoint. However indirect measurement is often the only way of
appraising the results of rural sanitation programmes, especially in primitive
or unorganized areas and where a complete medical team is not available

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* Macdonald, G. (1953) The appraisal of the results of rural sanitation programmes
(Unpublished working document WHO/Env. San./37)
for making morbidity surveys. The data upon which indirect measurement is based are those which are normally collected in the course of community sanitary surveys.

Both pre- and post-operative community sanitary surveys will point to the need for further sanitation work in the area and will yield valuable information upon which future programmes may be based. These may have to be deferred for a while because of lack of funds or the necessity for preliminary stimulation of the interest of the local population. In the latter case, much will depend upon the initiative, the zeal, and the ability in public relations of the sanitation and other personnel in promoting new health and sanitation ideas among the population.

**Sanitary Regulations**

Basic legislation is necessary in order to enable a public health agency to initiate and develop activities in the field of public health and sanitation. Such legislation is normally passed by a legislature, a parliament, or a similar official legislative body of a country or state. The collection in an orderly manner of legislative acts in the form of public health or sanitary codes is done from time to time by the public health agency. Basic, or enabling, legislation is confined to statements of broad principles, responsibilities, and penalties. On the basis of such legislation, the public health agency concerned is in a position to formulate and issue more detailed rules, regulations, and standards relating to the organization and operation of local health work and to procedures for carrying it out. Also, ordinances dealing with such matters as the source of food and milk, the health and sanitation practices of persons who come in contact with them, the sanitary nature of processing equipment, the sanitary quality of water, and so on, may be issued by the public health agency in order to explain or qualify in detail the basic legislation enacted.

An existing sanitary code in a country may exert a strong influence upon the nature and content of a rural excreta disposal programme under planning. If the sanitary regulations are outdated or too elaborate or exacting, they may have too much of a restricting influence upon both the technical and administrative aspects of the programme. Such regulations defeat their own purpose and are usually ignored by the population. When suitably drafted, regulations are useful in helping to ensure a basic minimum of sanitary safeguards and the elimination of potential health hazards, especially in densely inhabited communities or industrialized rural areas. They usually deal with, and prescribe standards for, such matters as the prevention of soil and water pollution; the disposal of human and animal wastes; the hygienic aspects of housing; the protection of milk and other food supplies; the control of arthropod, rodent, and mollusc hosts of disease; and the use of surface waters.
When elaborating sanitary regulations, it is important to keep in mind the following principles, which have been set forth for milk, but which apply as well to all sanitary legislation:

1. No regulation should be made which cannot be enforced.
2. No law can be enforced without the co-operation of most of the persons concerned.

Rules and regulations applying to excreta disposal in rural areas should be reasonable and no more drastic than is necessary; above all, they should adhere to basic principles of sanitation. Only in this way can they be applicable at the same time to several (or all) rural areas within a given country. It is important to consider every contingency which may occur within the foreseeable future, and the best way to do so is to consult the people for whose benefit the regulations are formulated. While the experience of others may be useful in drafting new regulations, it is always a mistake to adopt the regulations of another country without making some necessary modifications.

On the need for the co-operation of the people in the enforcement of legislation, Lethem has written:

"No form of control can be effective without the support of most of the people concerned, backed by an enlightened public opinion. Hence, education must precede legislation; in fact, it might be described as the father of legislation. The lower the standard of education, the greater the need for careful preparation before new regulations can be introduced and enforced. It is better to start in a small way and work up, than to introduce a multiplicity of rules and raise a wall of opposition, which makes enforcement difficult. Legislation alone cannot improve hygiene. To launch regulations without first preparing the way, is like sowing seed without first ploughing the ground. Old traditions die hard, and bad habits are not easy to change."

This statement applies particularly well to excreta disposal programmes, which are designed to effect desirable changes in people's attitudes and practices. In this field public health instruction is more important than compulsion, and sanitary inspection should not aim at the enforcement of regulations by means of sanctions. Instead, it should be directed away from that concept.

**TRAINING AND FUNCTION OF THE SANITATION STAFF**

**Categories of Personnel Required**

Sanitation programmes in general, and rural excreta disposal schemes in particular, require for successful planning and execution a number of competent sanitary staff at various levels of responsibility. This staff includes public health (or sanitary) engineers, health (or sanitary) inspectors, health assistants, health aides, and village workers.
It is quite probable that rural sanitation work has been carried out in many parts of the world without sanitary engineers, but not without sanitary engineering. Often medical officers of health, assisted by health inspectors, are responsible for all phases of sanitation. However, experience has repeatedly shown that, because of the multiple engineering aspects involved, engineers trained in the sanitary sciences are needed at the highest possible level of the health services for the formulation, administration, and development of sanitation programmes, including rural schemes. On this subject, the WHO Expert Committee on Environmental Sanitation stated:

"The assumption, perhaps too widely made, that underdeveloped regions are not prepared for the services of the best-trained specialists in environmental sanitation can readily be contested. Countries of minimum resources are most in need of the highest expert service available, both for diagnosis of need and for planning of solutions. The relegation of these functions to less-adequately prepared persons results from a great misunderstanding of the complexity of the problems in environmental sanitation encountered in areas of low economic level. These problems require for their solution the impact of high intelligence, training, and experience, even when the number of persons possessing such qualifications is necessarily a minimum. It is unsound practice literally to send a boy to do a man's job."

Apart from a few public health (or sanitary) engineers, the numbers and types of the other officers to be trained will be governed, according to circumstances in countries, by: (a) the background education of the potential recruits, (b) the ability and capacity of the training establishment to train different grades simultaneously, and (c) the pattern of the health services, if any, into which the new staff will be integrated.

Whether a new training programme is aimed at producing sanitarians (health inspectors, assistants, and aides, as listed above) for general sanitation work, or for a specific rural sanitation scheme, it is perhaps preferable not to dissipate teaching resources, but to concentrate all efforts on producing a single type of sanitarian. In the case of rural sanitation programmes, the greatest need is usually for sanitarians of the "health assistant" or "health aide" levels. Such personnel are assigned to rural towns and villages, and work under the supervision of health inspectors who are posted in district headquarters.

Village workers are trained within the rural areas concerned, not necessarily in the same training school as the sanitarians. The training of such workers is directed towards the stimulation of the self-help movement, of which sanitation is only one of several elements. Village workers are usually trained to do specific jobs, such as latrine or well construction, or maintenance of hand pumps or other equipment.

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a The term "sanitary engineering" includes the public health aspects of all environmental conditions and situations the control of which is based upon engineering principles and the application of scientific knowledge. The terms "sanitary engineer" and "public health engineer", as used in this monograph, are interchangeable.
In addition to sanitation staff, foremen and workers must be trained in the construction practices and procedures adopted for field application in the excreta disposal scheme.

Function of Sanitation Personnel

The nature and scope of the training of the rural sanitation worker engaged in the excreta disposal programme depend primarily upon the function which he will be expected to discharge. Sometimes training schemes are initiated without a clear understanding of what sort of health worker is wanted and what jobs the sanitarians are expected to perform. As a result, the sanitary produced under such training is likely to be disoriented and dissatisfied when confronted with rural problems and situations for which he finds himself unfit, and he may decide to quit the job, thus creating an undesirable turnover of laboriously trained staff.

In order to determine the functions of the future sanitarians, it is necessary to study such matters as the national sanitation plan (if one exists) of the country concerned, the present organization and responsibilities of health services and municipal administrations, and the country’s general health and sanitary conditions to which attention will have to be paid in the future. The duties of the various categories of sanitarians may be described in general terms as:

1. making preliminary surveys of a district, recording its sanitary conditions, and participating in the formulation of a plan of action for their improvement;

2. carrying out programmes of practical sanitation based on 1 above;

3. establishing good relations with the public, and educating the public in health matters;

4. maintaining active collaboration in all of the duties mentioned above with other services whose activities have a bearing on environmental sanitation.

The health (or sanitary) inspector must be able to perform all these duties. The work of the health assistant will be concerned mainly with item 2, and he should perform duties 1, 3, and 4 under direct supervision. The health aide should be limited to duties under 2. This distribution of functions among the sanitation staff will, in most cases, be well suited to the execution of programmes of excreta disposal in rural areas.

Conditions of Service

In planning a training scheme for sanitarians, it is necessary to consider the future conditions of service, including such matters as the possibility of personnel rotation from urban to rural areas and vice versa, the scales
of pay and allowances which will be granted to this sanitation personnel, and their chances for promotion. Since the duties of sanitarians range over a broad field of activities, their status and emoluments should compare favourably with the pay in similar professions. These should preferably include periodic within-grade increases for satisfactory performance and promotions to higher grades, eventually to supervisory positions. In rural sanitation programmes, the need for supervisors will arise at a relatively early date and will be more and more pressing as the activities expand. The supervisory positions should be filled from the ranks of the inspectors. While at the beginning these promotions may be made on a somewhat informal basis, they should eventually become a part of the personnel policy of the health departments concerned. In some countries a system of rewards for good work has been found to be desirable to help maintain a high morale among the staff and to reduce turnover.

Selection of Trainees

A discussion of this subject raises several questions of an economic, educational, and social character. Men of high calibre and education will almost always perform the best work in sanitation; but, of course, they are usually the most difficult to recruit, and demand higher salaries than those which may be offered to them. On the other hand, people willing to accept very low pay are often incapable of sustaining the effort and interest necessary for the long-range success of rural sanitation undertakings. It is therefore necessary to study the local scene and to offer scales of pay and allowances sufficient to attract "trainable" persons.

The level of general education of the potential recruits may be another stumbling-block. It is desirable to investigate the curricula of local schools as well as the teaching methods used in these schools. The information obtained will point to certain gaps in general education which need to be filled before technical subjects can be taught. It has been suggested that: 43

(a) the educational background of health inspectors should be the equivalent of some twelve years of education from the beginning, and should be sufficient to permit them to matriculate at a university;

(b) the educational standard for health assistants should be the equivalent of at least seven to eight years of education from the beginning, or in some countries to that of the highest class in the elementary school;

(c) in the case of health aides, the standard of education may be elementary, comprising reasonable competence in reading, writing, and simple arithmetic.
It is always wise to choose men from the small towns and villages where the rural sanitation work is to be done. These men are accustomed to rural life and are not apt to get discouraged too quickly when facing the challenges of the job. Staff turnover is always greater among persons recruited from cities, even though the cities may be within the same general area or province concerned. Family status of recruits is also an important factor to consider. A good rule is to start training single men (for they are much more mobile), or at least to keep married sanitarians in the towns from which they were recruited. The suggestion has been made that women might be trained as sanitarians who could perform duties in places inaccessible to men. In addition to the above-mentioned qualifications, sanitarians should be selected among persons exhibiting good character, personality, and integrity.

Training

It is desirable that sanitarians should be trained within the country concerned and, preferably, at a centre located within a region possessing the same general characteristics as the rural area where the sanitation programme will be developed. Facilities such as health centres and laboratories, hospitals, water and sewage works, and refuse disposal and other sanitary installations should be available for the practical demonstration and training of the students. In fact, most of the duties of sanitarians are of a practical nature, and their training should therefore be essentially operational. Much of the teaching should take place outside the classroom during field visits and inspections, and the theoretical lectures should relate as much as possible to field applications. Such training will aim at developing the trainees' abilities in observation, criticism, and constructive suggestions. Particular care should be taken to stress the future advisory and teaching role of thesanitarian and to combat the idea of police-power inspection.

In reviewing the literature on the subject of training of sanitarians, it is noted that the duration and contents of courses differ widely throughout the world: training courses vary from five weeks to three years, and the course material from application of simple sanitary measures through class work and closely supervised field exercises to academic work of university calibre with field training in health departments. This might well be expected, for each training course has been developed in the light of the customs, history, needs, and health programmes of the country concerned. The WHO Expert Committee on Environmental Sanitation has suggested courses which might be included in the training programmes for various categories of sanitarians (see Annex 1, p. 175).
Unless one has had long teaching experience, the first training course and the beginning work in community sanitation in rural underdeveloped areas are likely to be more enlightening to the teacher and administrator than to the students. With a large class and a long course, the investment of resources—e.g., for school buildings, transportation facilities for students, demonstration and library materials, and equipment—is apt to be considerable; yet it is difficult to foresee all the personnel needs of the sanitation programme, as well as the reaction of the students to the courses presented. For these reasons a pilot type of training school may be desirable in the first instance under such a situation. After the sanitation work has been going on for a while, the needs for personnel and for a particular type of training will be better defined, the less capable students and staff will have been weeded out, and it will then be possible to readjust the training programme accordingly.

Another advantage in starting the training scheme on a small scale is the aid this gives to good supervision and leadership of the trainees, particularly from the standpoint of the supervisor. It is fallacious to believe that the sanitarians, upon the completion of a short training course, are capable of solving all kinds of problems. The majority of them will be going into the field with considerable uncertainty and, if left by themselves too long a time at the beginning of their career, may either fail or get off on the wrong track. To avoid this, it is necessary for the supervisor to visit them frequently.

This feeling of uncertainty on the part of the sanitarians can also be considerably reduced if their training has prepared them to do a limited number of jobs very well—a point which cannot be emphasized too much. It is not wise to give the trainees a great deal of vague, theoretical notions and to expect them to go out into the field and be successful. Such training is bound to lead to failures; and, what is worse, the sanitation programme itself may fail or receive an irreparable setback. The training should be highly objective and should be designed to make the men confident and aware of where to start, how to start, and where to go.

A compendium of the lectures and field notes should be given to the new sanitarians at the end of the course. This will serve them as a reference on problems which often arise and for which there is no clear-cut solution.

In most instances, training courses are initiated under the conduct of teachers selected from among existing health department personnel. However, it is acknowledged that the training of sanitarians is an exacting task which requires at least a nucleus of full-time and experienced teachers, preferably possessing previous knowledge of teaching principles. Such teachers should be able to develop training manuals written in the local language and adapted to local problems and to the educational level of trainees. Foreign books should be used only as references.
In planning the training programme, provision should also be made for various extension activities designed to widen the influence of the school, to establish a link between the teaching staff and the health activities in the territory, and to encourage and follow up the work of the former students. The following types of activity are suggested:

(a) Team-work in varied regions, possibly under the supervision of the teaching staff. This may be a very desirable activity immediately after the course, where the qualifying students are young and inexperienced, or where the governments have insufficient health staff to provide the necessary supervision.

(b) Refresher courses. Such courses give everyone a chance to develop, and offer encouragement to the sanitarians, who feel that the health department is paying attention to their welfare. The sanitarians do not have to absorb much new material at any one sitting, and the engineer can develop the sanitation programme more objectively in the light of what his whole staff can learn and contribute in such courses.

(c) Conferences, seminars, dealing with one or two special topics.

(d) Health weeks, with the participation of schools and the public.

(e) Promotion courses, preparing lower-level sanitarians for upgrading.

Utilization of Sanitarians

Proper utilization of sanitation personnel is as important as their training, and should be based on the principle that each sanitary should fill a position fitted to his grade and training. To sanitarians who are beginning rural or community sanitation work there is nothing so important as success; and success will come much more easily and quickly if the scheme provides for concentration on objectives limited in number and scope to what the sanitary can achieve at any one time. Such a technique is the surest and quickest way to get to a broader programme. A latrine project is excellent as an initial objective, provided the health department is prepared to contribute leadership and its proper share of funds, materials, and supervision, the last by means of sanitarians assigned to each community.

It is important that the sanitary be assured at all times of the full material and moral support of the health authorities. This is especially true in the initial stages of his work in a new area. He will need encouragement and recognition from his superiors. Above all, his talents should not be misused by making him a “Jack of all trades”.

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ANNEXES
Annex 1

EDUCATION AND TRAINING OF SANITARIANS *

Sanitarians

Health inspector

A large part of the training of the health inspector should consist of practical demonstrations with a period of experience in a health department. The course should be so designed that the subjects may be expanded to higher stages to enable the health inspector, with further study, to advance, if he is suitable and so desires, to the academic course. He should be imbued with a spirit of inquiry and enthusiasm for public health ideals. The basic idea is to educate and train a good general practitioner of environmental sanitation.

The courses of study should include the elements of the following subjects: mathematics, physics, chemistry, bacteriology, parasitology, epidemiology, anatomy, and physiology; the control of communicable diseases; disinfection and disinfection; water-supply and treatment; sewerage and sewage treatment; the collection and disposal of refuse and excreta; insect and rodent control; factory inspection; building construction, including drainage, septic tanks, soakage pits, and the like; and the drawing and examination of simple plans. The health inspector should be instructed in the inspection of meat and food-stuffs and the procuring of samples for analysis, and be able to deal with special sanitary problems in places such as hospitals, schools, airports, mines, etc. He should also receive instruction in public health administration, statistics, legislation, and legal procedure.

Health assistant

The education and training of the health assistant should be designed so that he may play an important part in environmental sanitation in urban and rural areas under suitable direction. The course of study should provide ample time for practical demonstrations. The subjects taught should include: very elementary anatomy and physiology; mensuration, simple geometry, simple arithmetic, and sketching; general hygiene, causes of disease, and sanitation, including air, water, and food. The course should provide some instruction in communicable diseases, disinfection and disinfection, case investigation and control methods,

* Reproduced from the second report of the WHO Expert Committee on Environmental Sanitation.23
elementary medical entomology and elementary helminthology, collection and disposal of refuse and night-soil, with some information on the more complex sewerage, sewage disposal, and water-supply systems. The health assistant should also be instructed in food inspection, with visits to food production establishments; in nutrition; in rodent and insect control; in the use of artisan's tools and the construction of latrines and privies; and in personal hygiene. He should be encouraged to promote health education in rural communities.

**Health aide**

Under suitable direction the health aide would be a valuable person in the promotion of rural sanitation. His instruction, therefore, should include a knowledge of sanitary work as applied to rural areas, such as the raising of the standard of housing, the improvement of rural water-supplies, and refuse and excreta collection and disposal. The course should include elementary understanding of the factors concerned in the spread of the common communicable diseases in relation to sanitation. It should also include the preparation of simple hygiene reports and the keeping of a diary. The health aide should be able to recognize local insect pests and rodents and be instructed in disinfection and disinfestation. He should be able to construct simple sanitary works.

**Voluntary Leaders for Mobilization of Self-Help**

The people in this category cannot spare the time for long and formal education far away from their homes. Short but intensive training for about two weeks has been tried and found sufficient.

The curriculum should be simple and practical. Besides explaining the causes and mode of communication of the most important diseases prevailing in the area, the curriculum should emphasize the need for personal hygiene, sanitation of the environment, and maternal and child care. It should also provide data on, and point out sources of, materials and skilled service that may be available to the local people for improving the environment, and for constructing sanitary facilities such as wells for safe water-supplies, or sanitary latrines.

The trainee will have to be taught in the language of the locality. In the case of volunteers and village schoolmasters, the period of training should be so chosen as to interfere least with their normal business.

After receiving training, the volunteers and trained teachers should be the chosen repositories of confidence of the local health-authorities in those matters which come reasonably within their competence, for example, the issue of insecticides.
Annex 2

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