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On-Site Excreta Treatment and Disposal in West Africa

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ON-SITE EXCRETA TREATMENT AND DISPOSAL IN WEST AFRICA

BY

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RESEARCH REPORT

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ABSTRACT

Wastewater collection, treatment and disposal is well developed in the industrialized countries. This is not the case for the developing and underdeveloped countries consisting of more than two-thirds of the world's population. Many areas in these countries are lacking the very basic sanitary facilities. Therefore, it is hoped to provide information on those principles and practices for on-site excreta treatment and disposal that are most likely to be used in those underdeveloped countries in Africa, with particular reference to Nigeria.

This study was directed to: (1) examine the literature on waste disposal systems in these countries, (2) determine the operating problems, and (3) determine alternative and economically more feasible systems with minimum environmental impact.

This study concluded that well designed and maintained septic tanks with the narrow trench type soil absorption field would be more favorable than other existing and alternate systems. Also, the clivus multrium composting system appears to be a promising alternate.

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CHAPTER I

INTRODUCTION

The technology required for the provision of wastewater collection and disposal services is well developed in the industrialized countries. For the fortunate housewife in this part of the world, safe water is obtained from the tap in her kitchen or bathroom at anytime of the day or night, and human wastes are simply flushed away by the water closet. This is not the case for the vast majority of people in the developing and underdeveloped countries constituting more than two-thirds of the world's population (WHO 1972).

During the past several years, there have been many developments in the field of disposal of human wastes, and many books have been written on this subject. The great majority of these dealt almost exclusively with sewerage and sewage disposal as applicable to cities and large towns and communities. A survey of the relevant publications and a few books published on rural sanitation revealed that latrines, wells and septic tanks were generally used for individual disposal systems; with very little mention of central collection systems.

In 1971 and 1972, the World Health Organization conducted a survey of community wastewater and excreta disposal conditions in seventy-one selected developing countries (WHO 1958). It was reported that in urban areas only 28% of populations were served by a public sewerage system, 39% by individual systems and the remaining were not served by any sanitary system whatsoever. In the rural areas, 92% of population completely lacked sanitary facilities. This situation which is very far from satisfaction, becomes worse in view of population growth.

It is known that developing and underdeveloped countries are characterized by limited financial resources (particularly foreign exchange); limited manufacturing capacity; limited skilled labor (but ample unskilled labor); and limited engineering resources for conceiving, planning, constructing, and operating collection and treatment systems. Therefore, the purpose and aim of this report is to provide information on those principles and practices that are most likely to be appropriate to these underprivileged countries of Africa, with particular reference to Nigeria.

Nigeria

This country, with a population of 80 million people in an area of 375,000 square miles, on the west coast of Africa is bounded on the south by the Gulf of Guinea and on the landward sides by Cameroon, Chad, Niger and Benin, as shown in Figure 1. About as large as California, Arizona and Nevada combined, it has a hot, humid coastal belt of mangrove swamp; a belt of tropical rain forest; a high, dry central plateau of open woodland and savannah; and in the far north, semi-desert (Paxton 1982). Two seasons, dry and wet, are well-marked

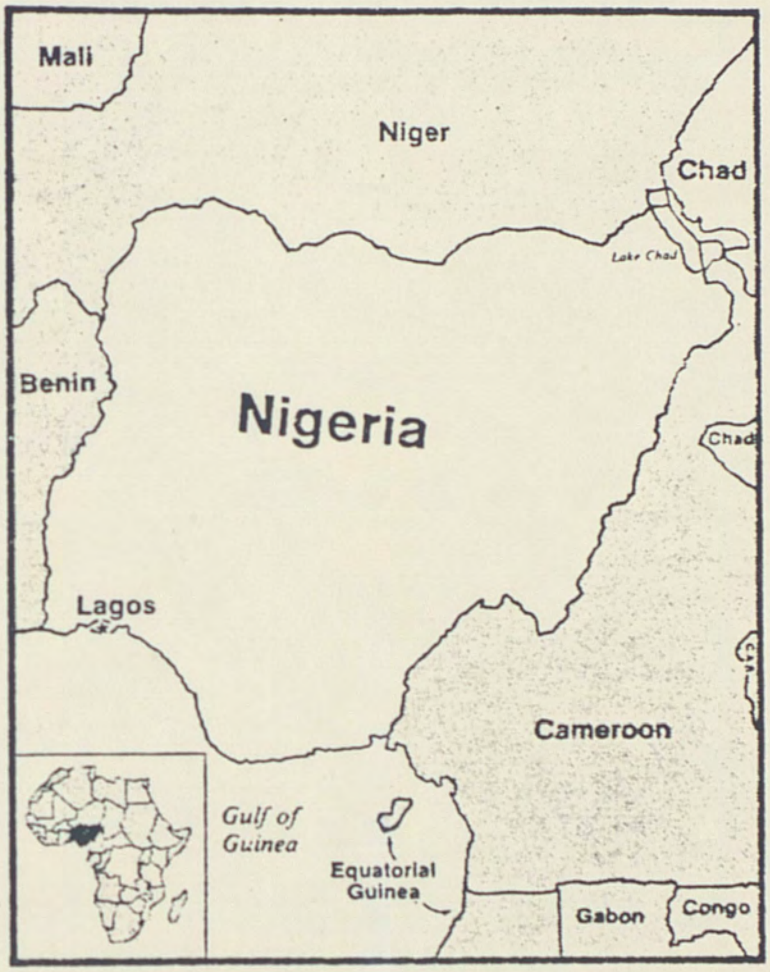


Fig. 1. Map of the Federal Republic of Nigeria.

SOURCE: Paxton, John. "Statistical and Historical Annual of the States of the World for the Year 1981-1982." <u>The Statesman's Yearbook</u>. New York: St. Martin's Press, 1982.

through most of Nigeria. Annual rainfall ranges from 150 inches on the east coast to 25 inches or less in the extreme north (U.S.D. L. 1980). Situated only a few degrees north of the equator, average temperature is high, though the north has cool nights because of the Sahara Desert's influence. In the south, excessive humidity is a problem.

There are 13 universities, five medical colleges designed to turn out 450 doctors a year, 200 colleges and college-level technical institutions. The variety of customs, languages and traditions among Nigeria's 250 ethnic groups gives the country a rich heterogeneity. The official languages are English with Hauza, Iko and Yoruba.

The standard of public health has not yet reached that enjoyed by more developed nations. According to U.S.D. Statistics, 1980, medical and health services are the responsibility of the state governments, each of which maintains hospitals in the large cities and towns. Medical services are generally scarce, especially in the rural areas where 80 to 90 percent of the population lives. There are shortages of doctors, other medical personnel and drugs. There areenormous sanitation problems: sewage disposal, water shortages, water pollution, and very poor drainage, which are complicated by inadequate knowledge of basic hygienic principles. Rural areas lack adequate and pure water supplies, tap water is not portable, and most available drinking water is from springs, wells and streams. Intestinal diseases, malaria and ring worm are very common.

Nigeria lacked much urban sewage disposal systems and the general method of waste disposal in rural areas was by open pit latrines and by latrine buckets that were collected by public employees at night and emptied into shallow trenches or pits. In some coastal areas, waste was dumped into creeks or rivers, and in other places, it was used as a fertilizer. Septic tank installations had become increasingly common with higher income households in urban areas, and most public buildings in urban areas were serviced by them (Nelson 1972).

There is a high rate of death, and it was reported that in 1960, 50 percent of all live-born infants died before the age of five, and in 1972, 45% died. There is no record for 1980, but it is believed that there is a marked improvement because of the federal government's strenuous efforts to improve the sanitation of the country.

Objective and Scope

The purpose of this research report is to: (1) examine the literature in search of available data on the waste disposal systems at the underdeveloped and developing countries, (2) determine the operating problems relating to the most commonly used system, and (3) determine alternative and economically more feasible system with minimum environmental quality deterioration.

The scope of this report will be limited primarily to the developing countries in West Africa, south of the Sahara, but techniques and methods developed in other areas will be incorporated herein.

CHAPTER II

LITERATURE SURVEY

Public Health Importance of Excreta Disposal

Excreta disposal is an important part of environmental sanitation. Its provision is listed by the WHO Expert Committee on Environmental Sanitation (1952) among the first basic steps which should be taken towards assuring a safe environment in rural areas and communities. In large areas of the world, proper excreta disposal is among the most pressing public health problem. WHO statistics show that well over twelve hundred million people in the developing countries are without reasonable access to safe drinking water because of improper disposal of human excreta that resulted in the contamination of surface waters, groundwater and the soil; thereby posing health problems (WHO 1976).

Relationship to Health

Poor excreta disposal is often associated with the lack of adequate water supplies and of other sanitation facilities and with a low economic status of the rural population. Although all of these conditions affect health in one way or another, there is also a relationship between the disposal of excreta and the state of health of the population. This relationship is both direct and indirect. The direct effect is exemplified by the reduced incidence of certain diseases when proper disposal of excreta is practiced. This group of diseases includes cholera, typhoid and paratyphoid fevers, the dysenteries, infant diarrhoeas, hookworm diseases, ascarias, bilhaziasis and other similar intestinal infections and parasitic infestations that are very common to tropical developing countries of Africa (WHO 1976).

A recent example of the correlation between water quality, excreta disposal and the incidence of cholera is in the district of Mulanje Malawi in Africa in the October 1973 to March 1974 epidemic. It was reported by Saunders (1974) that over three-quarters of the population in the area that was provided with a sanitary excreta disposal system were not affected by the widespread epidemic, while those with no adequate disposal system suffered severely.

Also in the state of West Virginia in the United States of America in 1954, the effect of sanitary excreta disposal on the incident of outbreak of typhoid and paratyphoid was reported by Fair (1954) as shown in Figure 2 . When a privy construction program was undertaken, the death rate attributed to these diseases was cut by two-thirds and eventually reduced to nil.

Evidence of these relationships may be found in a comparison of figures for infant mortality from diarrhoeas and enteritis in various countries, as shown in Table 1, compiled by Fair (1954). WHO (1952) reported that diseases associated with unsatisfactory sanitation (poor excreta disposal) are a major

TABLE 1

INFANT MORTALITY FROM DIARRHOEA
AND ENTERITIS FOR THE YEAR 1954

Country	Infant Mortality		Infant diarrhoea and enteritis	
	Age 0-1 year, total	rate per 1000 live-births	deaths[a]	deaths from diarrhoea and enteritis (%)
Egypt	81,407	179[b]	43,517	54.7
Colombia	48,734	103	6,277	12.8
Guatemala	14,302	88	1,392	9.7
Portugal	16,898	86	5,126	30.3
Mexico	107,853	80	21,052	19.5
Costa Rica	3,820	79	772	20.2
Puerto Rico	4,482	58	1,088	24.3
Panama	1.745	53	241	13.8
Italy	46,104	53	5,168	11.2
Uruguay	2,428	51	440	18.1
Austria	5,023	48	391	7.8
Japan	78,944	45	5,669	7.2
Germany, Federal Republic	33,353	43	443	1.3
Israel	1,417	35	198	13.9
Union of South Africa (European population)	2,298	33	277	12.0
Canada	13,841	32	554	4.0
Finland	2,750	31	199	7.2
USA	106,791	27	3,590	3.3
Denmark	2,051	27	64	3.1
Switzerland	2,280	27	42	1.8
United Kingdom of Great Britain and Northern Ireland	17,160	25	428	2.5
Norway	1,343	21	37	2.7
New Zealand (exclusive of Maoris)	968	20	17	1.7
Sweden	1,966	19	21	1.0

[a] Figures given in this column do not include deaths due to enteric infections in the newborn (babies less than four weeks old).

[b] Figure for 1953.

SOURCE: Annual Epidemiological and Vital Statistics, 1954.

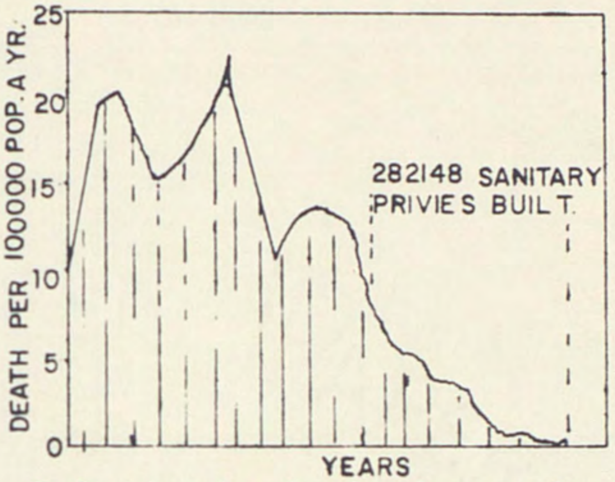


Fig. 2 . Reduction in the death-rate from typhoid by sanitation of excreta disposal.

SOURCE: Fair, G.M. and Geyer, J.C. Water Supply and Wastewater Disposal, p. 26, New York: John Wiley and Sons, Inc., 1954.

cause of low life-expectancy in developing countries as shown in the human survival curves for the industrialized and developing countries. See Figure 3.

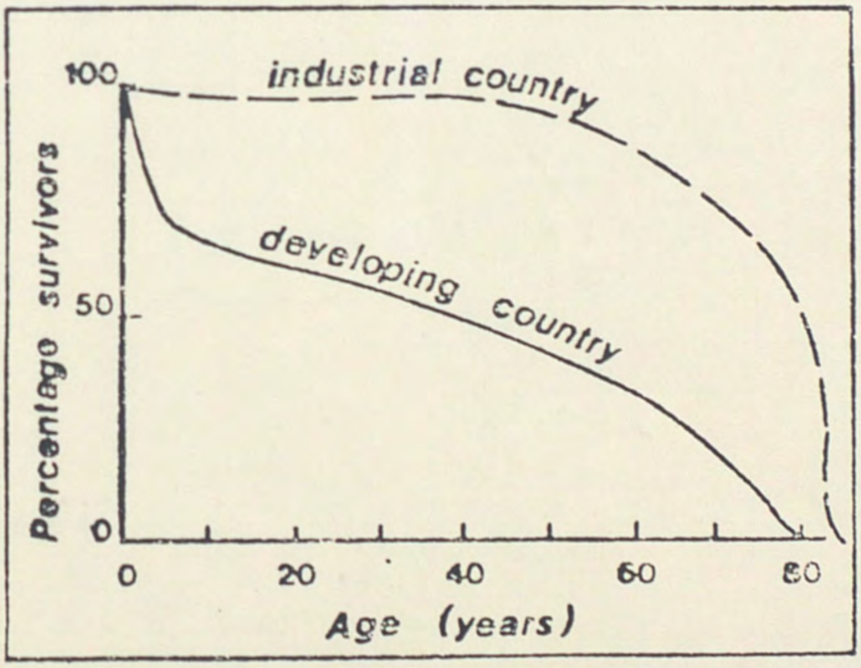


Fig. 3 . Human survival curves.

SOURCE: Pickford, John. "Appropriate Sanitation for Urban Areas and Villages in Developing Countries." University Tech. England, World Health Organization, Geneva 1979; 10, 593-608.

How Disease is Carried from Excreta

Man is the reservoir of most of the diseases that destroy or incapacitate him. The faecal-borne infections and infestations already mentioned are the causes of tremendous losses in death and debility; but they can be controlled through good sanitation (excreta disposal). John Pickford (1979) outlined these six factors that must be present in order to transmit disease:

1. a causative or etiological agent
2. a reservoir or source of infection of the causative agent
3. a mode of escape from the reservoir
4. a mode of transmission from the reservoir to the potential new host
5. a mode of entry into the new host
6. a susceptible host

The absence of a single one of these six conditions makes the spread of disease impossible. Transmission is mainly by water, food, milk, flies and other insects, and by direct contact. The technical objective of sanitary excreta disposal is, therefore, to isolate faeces so that the infection agents in them cannot possibly get to the new host.

Appropriate Technology for Excreta Disposal

It is increasingly realized that improved health may depend as much on good excreta disposal methods as on pure drinking water; and agents like flies, water, hands or clothing may carry the disease-causing pathogens from the excreta of one person to the mouth of another. The problem has been the adoption of proper technology to block the spread of these diseases. The conventional provision has always been the use of convectional sewerage and sewage treatment. This system may be very appropriate, but a look into its advantages and disadvantages will help in the decision of its application to a particular area.

From the engineer's point of view and the point of view of well founded authorities, the convectional sewerage system is very ideal and permanent. However, it should be realized that for every person served, about fifty liters per day of water is required to transport less than a liter of excreta; in some areas, the water used to carry excreta is the same as that for drinking. In most West African countries, only a privileged few have multiple water outlets in their homes, and even where the water pipes are adequate, water may only be available for a few hours a day (WHO 1976). Therefore, the convectional sewerage system which may be appropriate where there is ample water continuously and the necessary high cost can be afforded, and for concentrated high density accommodations where a large population is to be provided with sanitation at one time; may not be economically very suitable for the poor strickened countries.

Since the main purpose of sanitation is to prevent the passage of pathogens from excreta of someone suffering from a disease to someone else, convectional sewerage is not the only acceptable method. There is a wide range of available systems ranging from the removal of the excreta from the home to infiltration method and destruction of excreta usually by natural biological process. The range of options available is shown in Figure 4 (WHO 1979).

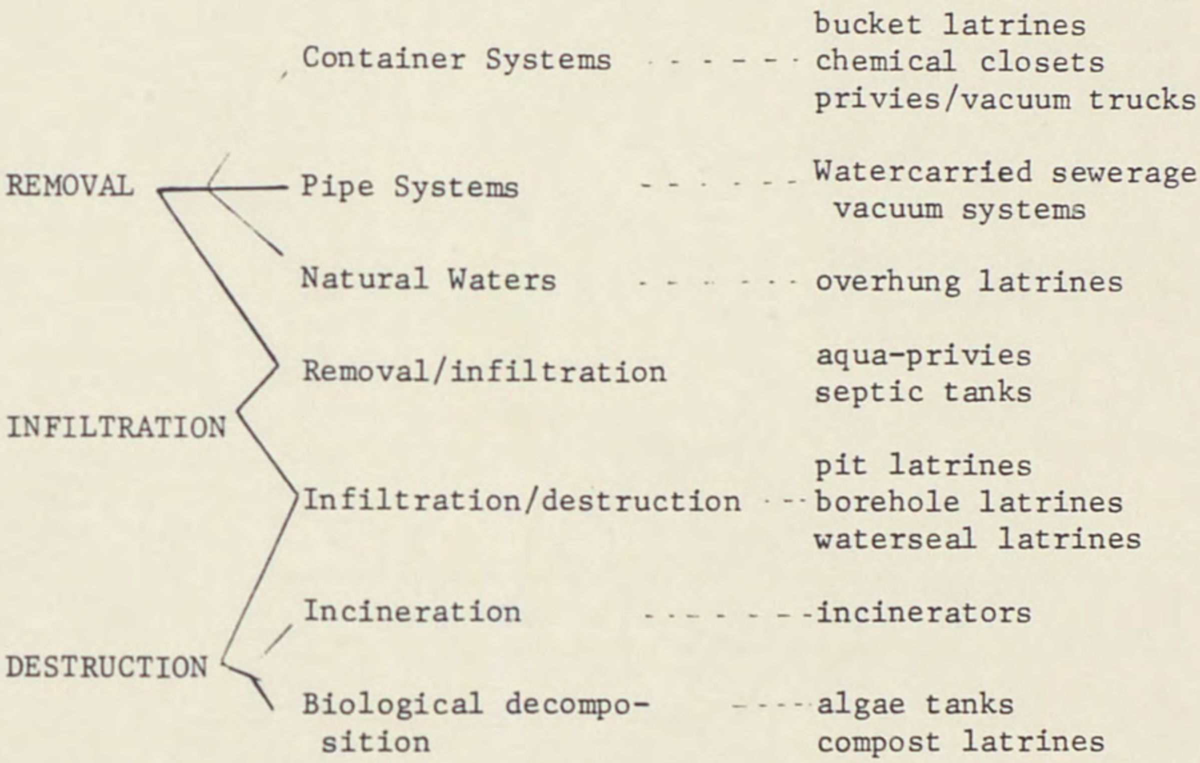


Fig. 4. Excreta disposal systems.

The adoption of any one of the above options should be based on the fact that like all good engineering, appropriate sanitation should satisfy the requirements for which it is intended and minimize the use of scarce resources that are plentiful. It should be appropriate for the local institutional and organizational conditions, habits, culture and sociological environment. And above all, the method of sanitation should be appropriate for the type and quality of maintenance which will be available, or the maintenance system should be made appropriate for the method of sanitation which is to be adopted.

Excreta Disposal Systems Presently in Existence

The various methods of excreta disposal systems in West African countries, south of the Sahara, range from the indiscriminant dumping of the excrement out of the shelter onto the adjacent land, to the convectional water carried sewerage.

At the interior villages where civilization has not yet shown its light, the system of disposal is by dumping the excreta on the field at the "back yard" on the farm land where it is utilized for agricultural purposes, while some of the excrements are carried to the nearby stream. Needless to mention, there is the greatest high death rate in these villages. Some of the people in this group practice pig-keeping, specifically to remove human feces.

In most of the rural areas with very poor and congested homes where labor is available, bucket latrines and similar "dry systems" are widely used. The container may not be as spacious or sanitary as a bucket. For example, in rural Lagos, empty car batteries are popular; in Accra, Ghana, baskets were common; in Congo, gourds; and elsewhere, earthenware pots; and every other place, empty oil cans are used (WHO 1976). The practice is distinguished architecturally in the external walls by tiny doors through which the filled bucket is removed. In practice, the contents are usually tipped into a larger container when filled and carried away on the cleaner's head, bike, wheelbarrow or ox-cart. This method is unsatisfactory. The cleaner's job is unhealthy. The container overflows, the contents are spilled, the latrine stinks and flies abound. This is often done at night, giving rise to the term "night soil".

Most of the disposal methods are shown schematically in Figures 5 and 6. A wide-spread use is made of the pit latrines and their adoption is probably the most cost-effective measure of the reduction of excreta-derived diseases in this area (WHO 1976). The latrine is a hole into which excreta drops, solids are broken down by biological activities and liquor infiltrates into the surrounding soil. The main types of latrines are: bore hole which is a deeper narrow pit, Reed's odorless earth closer (ROEC), and the water seal type as shown in Figure 7. Olunwande (1975) reports that cost of pit latrine is very low and excavation is merely done by the householder. Simple technological improvements such as the fabrication of squatting slabs under controlled conditions can be very beneficial, but this system could be very dangerous where the soil treatment capabilities are not adequate and where the groundwater table is very close to the surface.

The groups of people living along large bodies of water or at the marshy areas use the overhung latrine, which discharges vertically into the river. This might be appropriate if the river is flowing continuously and the water is not drunk untreated downstream or has a large dilution factor (Pradt 1971).

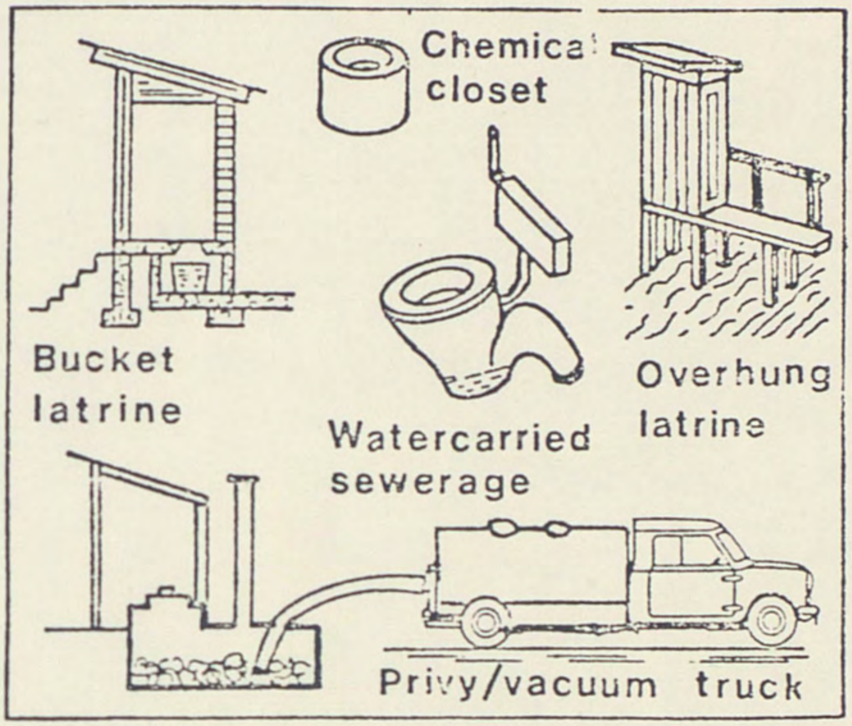


Fig. 5. Excreta removal methods.

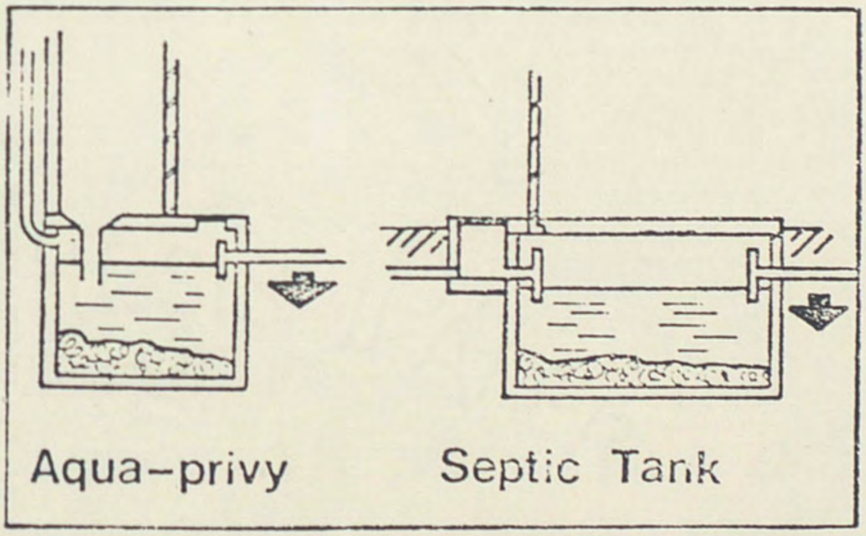


Fig. 6 . Removal/infiltration systems.

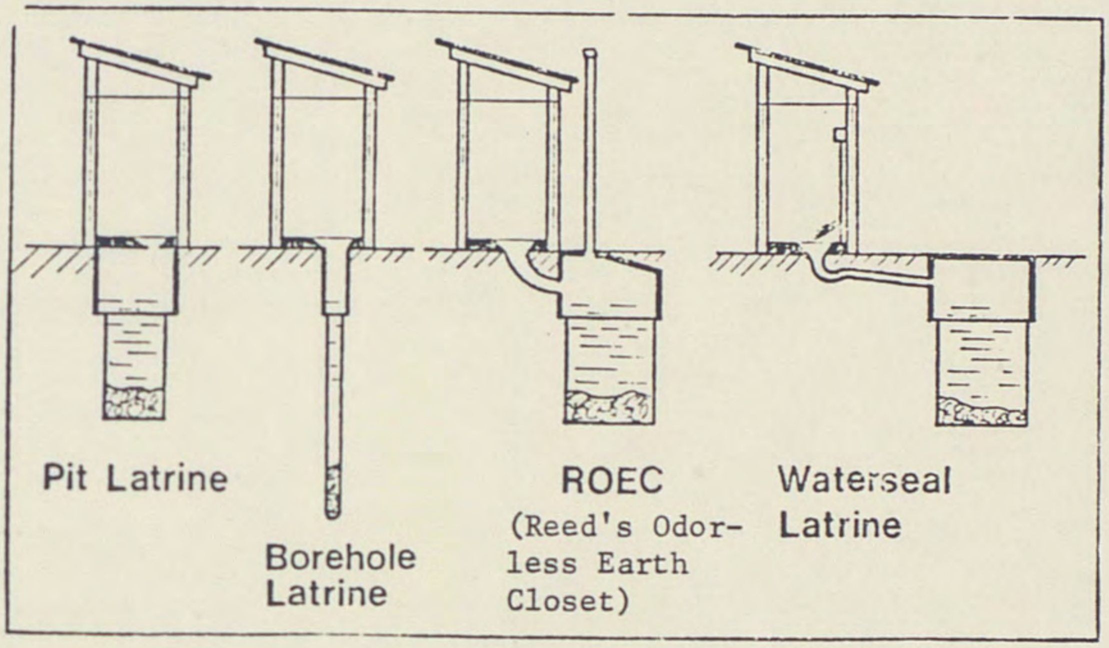


Fig. 7. Different types of latrines.

As one approaches the urban area, the use of vacuum lorries with privy vaults (Pradt 1971) becomes dominant as an example of the appropriate adaptation of a convectional system. Traditionally, in many of the eastern countries of West Africa, a small impermeable vault is built under the latrine seat. This is normally emptied through a little external door by a cleaner with a scoop who carries the night-soil away for agricultural purposes. In some places like urban Lagos, the system has been up-dated by using a vacuum truck to remove the vault contents regularly. In some places like Liberia, the collected night-soil is treated by advanced methods. The system appears appropriate; it eliminates the cleaner's contact with excreta, treatment reduces the danger of infected fertilizer spread on crops used as human food and water is not wasted as a transport medium. The cost is only one-third of the cost of sewerage and there is no need for wholesale digging up of streets usually associated with sewerage construction (Duncan 1976).

At the large cities, septic tanks are the most common light-cost sanitation device that is unsewered. They are normally used to treat water-carried sewage from houses with an ample supply of water and flushing water closets. The tank settles solids which breaks down biologically, and the liquid effluents percolate into the ground through a system of porous drains. In general, septic tanks give complete satisfaction, but Oluwande (1975) reports that this system suffers from the drainage field becoming blocked, hence rendering the whole system useless. More will be discussed on this system in the next chapter.

The aqua-privy is the most used system among the low-density high-class areas. It applies the same principles as the septic tank, except that the excreta is deposited directly into the chamber. No water carried sewerage is required, although sufficient water is added to replace evaporation losses. Some areas connect a sink for washing clothes or household utensils to the chamber which is released as a flush to clean the pan. The advantage over the septic tank is that a bucketful of water from a stand pipe is ample for several uses, the liquid effluent is very much less than from the septic tank and the area required for infiltration is much less. Aqua privies with soak-aways are appropriate for small housing plots with permeable sub-soil (Saunders 1974).

There are very few large cities in Guinea, Kenya, Liberia and Zambia that use the convectional water carried sewerage systems because of their industrial wastewater discharge. But their systems suffer in most cases from lack of maintenance, unreplaced rusted parts and lack of qualified manpower. And most do not function properly (WHO 1976).

For the well-off occupants of touring car/vans and holiday cottages, the chemical closet is widely used because it provides appropriate and odorless temporary storage of excreta which is later removed for disposal by burial.

Generally, except for the indiscriminant dumping of excreta, each of the existing methods of disposal discussed could be a very effective measure in the reduction of excreta-derived diseases if proper care, planning and maintenance are applied. Table 2 shows the survey by WHO on excreta disposal facilities in relation to the population served in West Africa.

TABLE 2

POPULATION SERVED BY EXCRETA DISPOSAL FACILITIES DECEMBER 31, 1970 BY TYPE OF SERVICE

Africa South of the Sahara	Urban Excreta Disposal Facilities											Rural with Adequate Disposal		Total	
	Connec. to Pub. Sewerage System					Household Systems				Total Urban					
	Conventional Treatment	Oxidation Ponds	Without Treatment	Total		Pit privy, Septic Tank	Buckets	Total							
	N'000	N'000	N'000	N'000	%	N'000	N'000	N'000	%	N'000	%	N'000	%	N'000	%
Burundi	---	--	14	14	14	80	---	80	82	94	97	---	--	94	3
Central African Republic	---	--	1	1	0	397	---	397	100	398	100	15	1	413	27
Chad	---	1	---	1	0	28	---	28	11	29	11	13	0	42	1
Dahomey	---	--	45	45	12	240	60	300	81	345	93	17	1	362	13
Guinea	14	--	46	60	13	391	---	391	87	451	100	60	2	511	13
Ivory Coast	---	--	110	110	12	65	45	110	12	220	23	---	--	220	5
Kenya	440	75	---	515	47	341	250	591	53	1106	100	4453	45	5559	50
Liberia	30	1	1	32	26	79	10	89	74	121	100	100	9	221	19
Madagascar	10	--	20	30	3	350	570	920	97	950	100	---	--	950	14
Mali	---	--	---	---	--	390	---	390	63	390	63	---	--	390	8
Mauritania	60	--	---	60	68	28	---	28	32	88	100	---	--	88	7
Mauritius	---	35	61	96	23	90	8	98	23	194	46	449	100	643	74
Nigeria	---	--	---	---	--	30	---	30	9	30	9	2	0	32	1
Uganda	100	26	24	150	22	435	6	441	64	591	85	7000	87	7591	87
Upper Volta	---	--	---	---	--	195	---	195	95	195	95	---	--	195	4
Zaire	---	--	25	25	1	200	---	200	7	225	8	875	6	1100	6
Zambia	42	21	---	63	6	92	4	96	10	159	16	550	16	709	16

SOURCE: Pineo, C.S., and Subrah Manyam. Community Water Supply and Excreta Disposal Situation in the Developing Countries, A Commentary World Health Organization, Geneva, 1975.

CHAPTER III

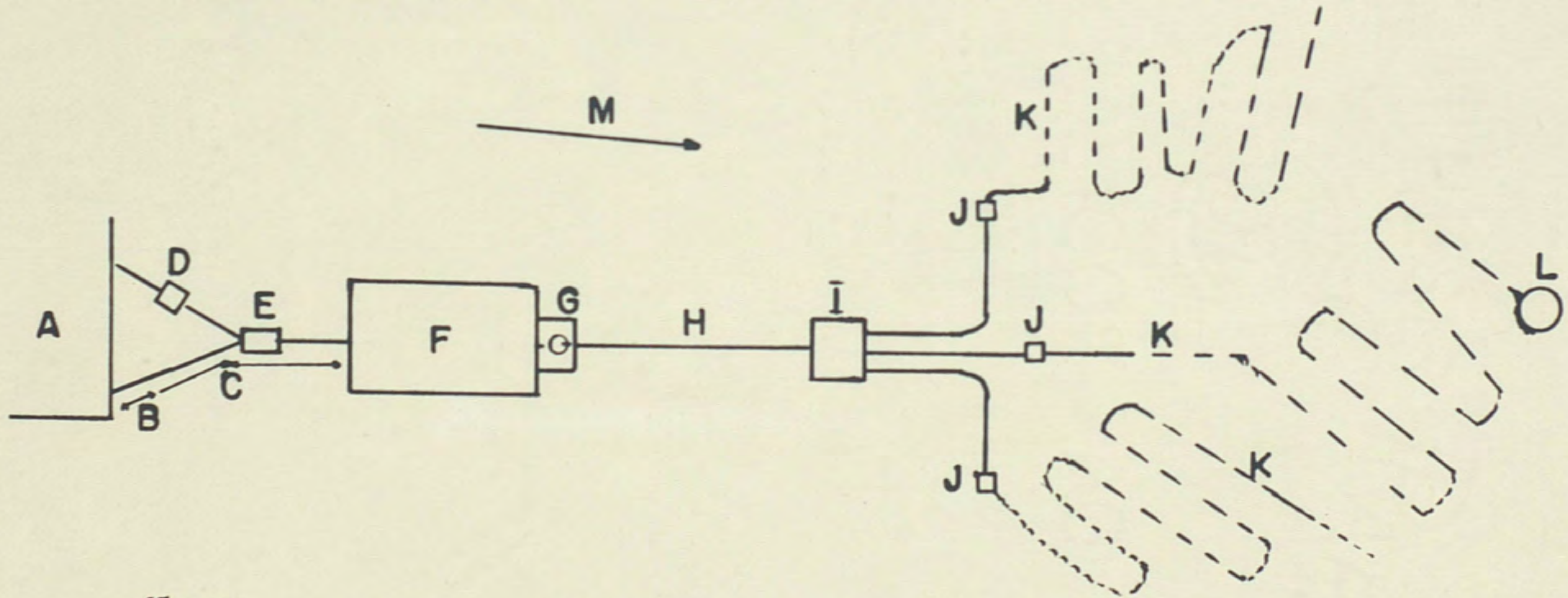
SEPTIC TANK TECHNOLOGY

From the survey data of the disposal systems in the rural and urban areas of the developing countries of West Africa as presented by Pineo (1978), it is evident that the most promising adequate treatment system will be the septic tank (see Table 2).

Septic tanks are buried, water tight receptacles designed and constructed to receive wastewater from a home, to separate solids from the liquids, to provide limited digestion of organic matter, to store solids (primary treatment), and to allow the clarified liquid to discharge for further treatment (secondary treatment) and disposal. Settleable solids and partially decomposed sludge settle to the bottom of the tank and accumulate. A scum of light-weight material (including fats and greases) rises to the top. The partially clarified liquid is allowed to flow through an outlet structure just below the floating scum layer. Proper use of baffles, tees and ells protects against scum outflow. Clarified liquid can be disposed of to soil absorption systems, soil mounds, lagoons or other disposal systems. Jones (1980) reported that leakage from septic tanks is always considered a minor factor; however, if tank leakage causes the level of the scum layer to drop below the outlet baffle, excessive scum discharges can occur; and in the extreme case, the sludge layer will dry and compact, and normal tank cleaning practice will not remove it. Secondly, if the tank is not water-tight, infiltration into the tank can cause overflooding of the tank and subsequent treatment and disposal components problems.

From Figure 8, the sewer line is recommended to be split as shown: lines from the kitchen and bath; the other from the water closet. The split line helps to reduce the amount of grease and oil from the kitchen and bath at the grease interceptor (D). The man-hole, which is small in size and connects the two lines, is important because it provides for inspection and an access to locate blockage when it occurs. The tank is made of the components as shown in Figure 9; and it is located in such a way to permit easy drainage from the dwelling and to the effluent disposal system. Because of periodic inspection, the tank is buried no more than 12 to 15 inches below ground level, and precautions are taken to prevent the entrance of surface runoff into the tank. The tank cover should be strong enough to withstand the weight of earth cover and occasional extra loads. Beside the tank is a dosing chamber, it is also called an inspection chamber. It could be used also for siphoning in case of blockages.

The distribution box, as its name implies, is a chamber which ensures an even distribution of the effluent to the subsurface disposal field through the drain pipes. 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



Where:

A = private house or public institution	E = manhole
B = house sewer	F = septic tank
C = building sewer (that part of the horizontal piping of a building drainage system extending from a point usually 5 feet outside of the inner face of the foundation wall in the septic tank)	G = dosing chamber and siphon
	H = pipes laid with tight joints
	I = distribution box
	J = drop-boxes or terracotta L's (hard semi-fixed water-proof ceramic clay)
	K = absorption tile lines
D = grease interceptor on pipe line from kitchen	L = seepage pit, when required
	M = slope of ground surface

Fig. 8. Typical septic tank layout system.

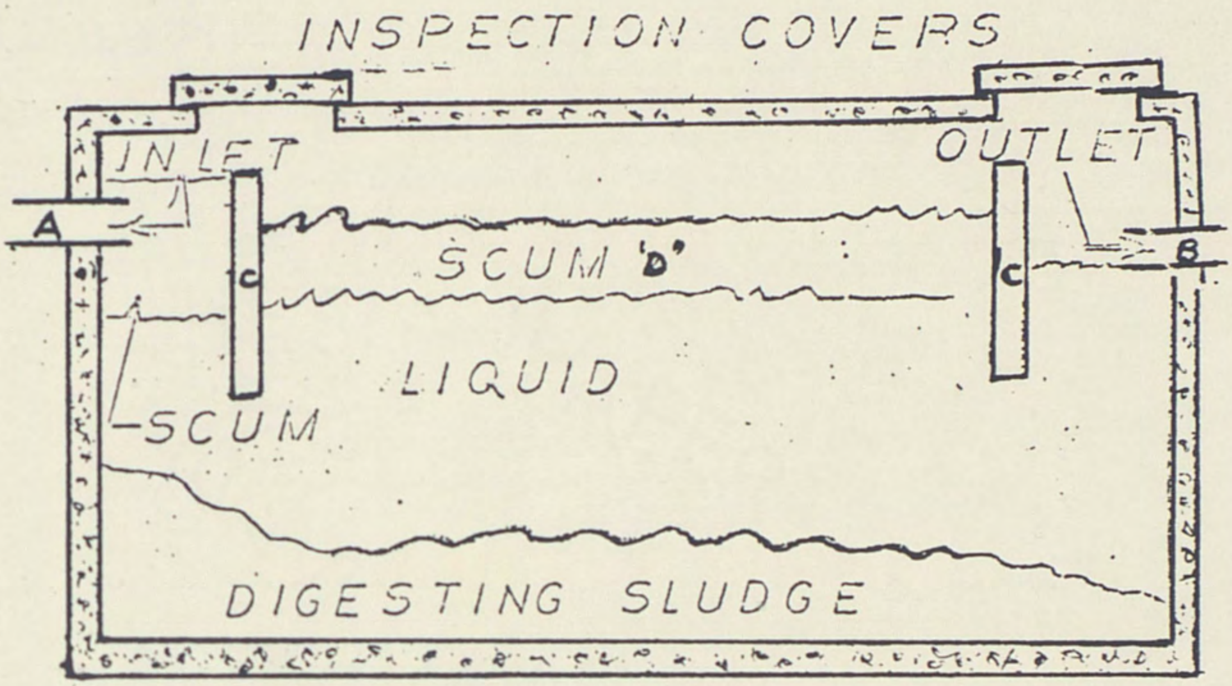


Fig. 9. Typical household septic tank.

where: A = inlet

B = outlet

C = baffle

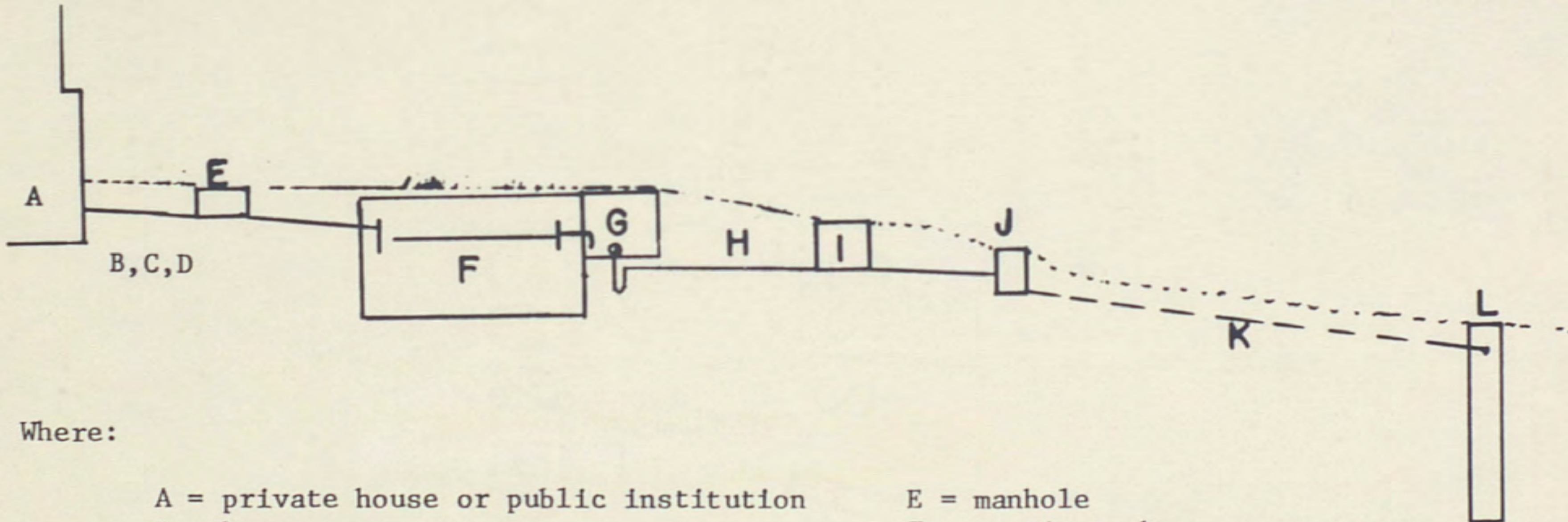
D = floating scum

proper distribution of effluent. The box 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 required. Experience has shown that an outlet may become partially obstructed by floating matter from the septic tank, if the tank 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.

The drop box or terracotta is a hard surfaced water proof ceramic clay box that receives the effluent from the distribution box. The effluent drops as shown in Figure 10 at "J" to provide for more depth on the slope and for partial mixing.

From the house to the drop box, the pipe is laid in such a way that all the joints are water-tight and protected from damage by roots where ever necessary. The absorption tile line could be of the narrow trench or bed system type as would be described later.

Since subsurface soil absorption is usually the preferred method of disposal, site evaluations center around the soil's capabilities to absorb and treat the wastewater over a reasonable length of time. Among the important characteristics is the knowledge of how water moves into and through the soil. Water moves through the voids or pore spaces within the soil. Therefore, the size, shape and continuity of the pore spaces are very important. To be able to determine



Where:

A = private house or public institution
B = house sewer
C = building sewer (that part of the horizontal piping of a building drainage system extending from a point usually 5 feet outside of the inner face of the founcation wall in the septic tank)
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 (hard semi-fixed water-proof ceramic clay)
K = absorption tile lines
L = seepage pit, when required
M = slope of ground surface

Fig. 10. Cross-section of a typical septic tank and absorption field layout.

their important characteristics, the knowledge of the following are required:

1. Soil texture, which is a relative proportion of the various sizes of the solid particles in the soil that are smaller than 2 mm in diameter. Soil texture is important because it is closely related to the aeration and drainage of the soil because of the pore size and continuity influence. Very small pore sizes with no continuity indicate poor permeability.

2. Soil structure, which refers to the aggregation of primary soil particles into clusters of particles.

3. Soil color, which is a result of the color of primary soil particles, coating of iron and manganese oxides and organic matter. Natural soil colors are red, yellow, brown, gray, blue or black (Otis 1981). These are used to predict the natural soil drainage. Yellow or brown indicates that the soil is well drained; and seldom or never saturated with water.

4. Bulk density, which is the ratio of the mass of the soil to its bulk or volume. Soils with higher bulk density are more dense with less pore volume and, therefore, less permeability.

5. Clay mineralology (to determine the rate and extent of shrinkage of the soil), some clay minerals such as montmorillinite shrink and swell appreciably with changes in soil moisture. Even small amounts of swelling clay can affect the soil permeability dramatically due to large cracks that open and close with wetting cycles.

The objective of the site evaluation is to investigate the characteristics of the area for their potential to treat and dispose of wastewater. The sequence of evaluation includes the lot description (location, size and shape, general features); wastewater characterization (type: domestic, commercial, industrial); volume (daily, average and peak flow, seasonal variation, future increase); important characteristics (grease, solids, settleability vs. non-settleability, BOD); soil surveys (content of soil and use of soil: farming, woodland, recreation, etc.); field testing (visual survey: general site features, landscape position, flooding hazards, vegetation, slope); and soil boring (using hand auger to determine soil variability, pits digging around the site perimeter).

Hydraulic conductivity follows if the soil boring indicates soil suitability for subsurface disposal. Several methods of measuring the soil's ability to transmit water have been developed. The "percolation test" is the most commonly used, and this gives an approximate measure of the soil's saturated hydraulic conductivity. Common errors in the falling head percolation test include poor hole preparation, inadequate soaking and inaccurate measurements.

The percolation test procedure is as follows:

1. Select number and location of tests; a minimum of three percolation tests, spaced uniformly.

2. Preparation of test hole; diameter of each test hole is 6 inches; dug to expose the natural soil surface, and filled to a depth

of two inches with 1/2 to 3/4 inch gravel to protect the bottom from scouring when water is added.

3. Soaking; fill hole with at least 12 inches of clear water, and maintained for at least 4 hours to the 12 inch depth level; this is important to allow sufficient time for soil to swell.

4. Measurement of percolation rate; this is made 15 hours after the soaking period, water level is measured from a fixed reference point to the nearest 1/16 inch at 30 minute intervals. After each measurement, the water level is readjusted to 6 inch levels.

5. Calculation; this is made for each test hole, and is in terms of minutes/inch (e.g., if the last measured drop in water level after 30 minutes is 5/8 inch, the percolation rate is 30 minutes x 5/8 inch - this is equal to 45 minutes/inch).

Tank Size

The principal factors that influence the capacity of the septic tank are:

1. the average daily flow of sewage

2. the retention period, from 1-3 days, usually 24 hours

3. adequate sludge storage, provide for adequate storage of sludge to enable removal every 2 to 5 years

Wagner (1958) recommends that for:

1. flow between 1900 l and 5700 l (500 and 1500 US gal.) per day, the capacity of the septic tank is normally equal to 1-1/2 days sewage flow.

2. flows between 5700 l and 37,850 l (1500 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: $V = 1125 + 0.75Q$, where: V is volume of tank in U.S. gallons and Q is the daily sewage flow in U.S. gallons (U.S. EPA 1980).

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

Operational Characteristics

McGauhey (1975) outlines some operational characteristics of the septic tank and the disposal system as follows.

Septic Tank

1. Produces sludge which is usually removed every two to five years.

2. Produces anaerobic effluent with offensive odor, high viral, bacterial and/or pathogenic content.

3. Proper operation should consist of annual inspection with sludge removal whenever necessary, leaving 6 to 12 inches of "seed" sludge.

4. Sludge must be disposed of in a satisfactory manner, according to local regulations, each three to five years average service.

5. Treatment of wastes is usually satisfactory with good liquification and reduction of waste solids.

Disposal System

1. The types outlined are: Dilution, narrow trench, wide trench or seepage bed, cesspool, seepage pit, mound system and evapotranspiration.

2. Failures of the wastewater disposal system are usually due to the failure of the disposal system rather than the septic tanks.

3. Most effective disposal system seems to be the narrow trench. The trench is 12 to 18 inches wide, with 4 inch open joint tube perforated plastic pipe located in 8 inches of crushed stone fill. The system is located in aerobically biologically active zones in the top two to three feet of soil as applicable to the tropic zones or hot climate.

4. A good trench system in applicable good soil may fail because of:

a. continuous innundation of the infiltrative surface causing an aerobic clogging

b. overloading of the system because of inadequate surface area

c. consolidation of the trench bottom and side during construction by mechanical compaction

d. dependence upon codes, percolation tests and political clout, rather than soil science, to identify soil capable of accepting water at a satisfactory rate

e. improper operation of the septic system primarily by allowing trickling of the effluent from the tank. A design discharge filling the infiltrative system then allowing drying before the next dose is more effective

f. an abrupt change of particle size should be avoided at the original infiltrative surface

g. the infiltrative surface should be vertical or some angle above horizontal in as large a percent possible under the trench design selected

Septic Tank Effluent and Surface-Groundwater Relationship

The nutrients in a septic tank effluents were determined by Hall (1975) and other researchers, and it was found that the effluents studied closely approximates the nitrogen and phosphorus content of domestic sewage effluent from central treatment plants, as such presents the same enrichment capability to surface waters in the absence of other large nutrient sources.

There are several effluents from septic tanks which may enter surface waters through the following processes:

1. Overland flow resulting from clogged absorption fields or high water table. This may not be a major problem to the Hinter land inhabitants of West Africa, but for the coastal inhabitants this may be a major problem since the water table is within one to two feet of the surface (Olunwande 1975).

2. Direct flow through fractures or eroded channels in rocks or impermeable soil (hard pan). For the area of concern, the author does not have any data as to how much of a problem this would pose, but from the author's experience, Nigeria has good enough rocks, but the impermeable soil is down very deep, enough

to require travel through sand/soil before the effluent reaches the impermeable soil.

3. Effluent flow through porous media, primarily sand, which is a desirable condition since the absorption mechanism of the soil acts on the effluent during the travel through the porous media as shown in Table 3.

The main portion of the nitrogen in the septic tank effluent is in the form of organic or ammonia (NH_3 or NH_4^+) as shown in Table 4, based on studies by Hall (1975), Brandes (1980) and others. It is concluded that nitrogen forms will be converted to nitrates (NO_3) in the first few inches of aerobic soil surrounding the absorption field in a good system. Since nitrates are soluble and chemically inactive in aerobic soil and require anaerobic soil conditions and a source of biologically useful organic carbon for further denitrification, most of the nitrates in the septic tank effluents will eventually enter either the ground or surface water.

Phosphorus is not as easy to trace in soil absorption systems. Brandes (1980) and Hall (1975) cite several literature that show soils can immobilize large amounts of phosphorus by little understood and complex chemical reactions. They further state that there is evidence that the system can be overloaded and the phosphorus goes back to solution to be transported. There is the possibility of leaching in high groundwater table or percolation of phosphorus

TABLE 3

NITROGEN AND PHOSPHORUS IN SEPTIC TANK EFFLUENT

Parameter	Average Concentration	Researched by:
Nitrogen	(mg/1 as N)	
Organic	10	Dudley
Ammonia	35	Dudley
Nitrate		Dudley
Nitrite	0.5	Dudley
Organic	10	Biggar
Ammonia	25	Biggar
Nitrate	0.15	Biggar
Nitrite	0.003	Biggar
Organic	5.6	Popkin
Ammonia	24.6	Popkin
Nitrate	0.2	Popkin
Nitrite	2.01	Popkin
Organic	8.5	(Average)
Ammonia	28.2	(Average)
Nitrate	0.27	(Average)
Nitrite	0.021	(Average)
Phosphorus	(mg/1 as P)	
Total	25	Dudley
Total	10.4	Bennett
Total	8.2	Lake George
Total	26.4	Sanborn
Total	38.3	Sanborn
Total	21.7	(Average)
Phosphates	20	Biggar
Phosphates	20.8	Sanborn
Phosphates	35.5	Sanborn
Phosphates	25.5	(Average)

SOURCE: Hall, Millard W. "A Conceptual Model of Nutrient Transport in Subsurface Soil Systems," Water Pollution Control in Low Density Areas, pp. 56. Edited by W.J. Jewell and Rita Swan. Hanover, NH: University Press of New England, 1975.

TABLE 4

CHEMICAL REACTIONS OF NITROGEN DURING SEPTIC TANK AND ABSORPTION FIELD PROCESSES

From urine, anaerobic in septic tank:

$$NH_4^+ \rightleftarrows NH_3 + H^+ \qquad \begin{matrix} & NH_2 \\ \diagup & \\ C = O & \\ \diagdown & \\ & NH_2 \end{matrix} + 2H_2O \xrightarrow[\text{urease}]{\text{enzyme}} (NH_4)_2 2CO_3$$

From feces, anaerobic in septic tank:

$$\text{Protein (organic nitrogen)} + \text{bacteria} \rightarrow NH_3 + H^+$$

Reduction of ammonium carbonate, anaerobic in septic tank:

$$(NH_4)_2\ CO_3 \xrightarrow{\text{bacteria}} 2NH_3 + CO_2 + H_2O$$

Reduction of ammonia in aerobic absorption field:

$$2NH_3 + 3O_2 \xrightarrow{\text{nitrosomas bacteria}} 2NO_2^- + 2H_2 + 2H_2O$$

Reduction of nitrites in aerobic absorption field:

$$2NO_2^- + O_2 \xrightarrow[\text{bacteria}]{\text{nitrobacter}} 2NO_3$$

SOURCE: Sawyer, Calir and Perry L. McCary. Chemistry for Sanitary Engineers, McGraw-Hill Pub. Co., 1967, p. 422.

deficient water such as rainfall causing the phosphorus immobilized in the soil to go back into solution.

However, whatever the method of phosphorus resolution, the possibility still exists that ground and surface waters can be polluted by phosphorus to some significant extent by septic tank effluents (Leich 1978).

Viruses are always present in domestic wastewater. Sproul (1975) references several studies showing viral (very small, living particles - polio viruses of 0.02 microns diameter and which cannot produce outside a living cell) levels in domestic wastewaters varying from 32-107 plaque forming units per liter (PFU) and a peak concentration of up to 7000 PFU per liter in U.S. and 270,000 to 2,147,000 $TCID_{50}$/liter (tissue culture infectious dose to infect half of the tubes) in settled wastewater in South Africa. There is very little information available on virus removal in septic tanks in the United States, in fact, some increase in viral detection may result because of the breakup of fecal solids during sludge formation, liberating viruses to the solution.

The report by Sproul (1975) concludes that most virus removal is accomplished during soil absorption of the effluent by a combination of these three mechanisms:

1. viral adsorption
2. bacterial enzymatic attack
3. natural die-off

While the number of viruses is substantially reduced by travel through the soil or sand, there are almost always some viruses present after filtration. Sproul (1975) referenced some field experiences in St. Petersburg, Florida indicating that viruses were still present after five feet of filtration through sand in a spray irrigation experiment. This shows that undisinfected septic tank effluents can cause a serious health problem if they infiltrate into portable groundwater.

Septic Tank Sludge

Septic tank sludge or septage is the undigested solids and scum removed from the tank. These wastes are produced by four main processes occurring within the septic tank: solids separation, scum floatation, biological decomposition under anaerobic conditions, and solids and scum storage.

The quantity of septage collected will depend on: (1) the amount of wastewater produced, (2) the efficiency of the septic tank, and (3) the number of years of operation of the septic tank between pumpings. Bennett et al. (1975) shows that a decrease in temperature reduces the rate of the digestion process, and will result in increased sludge accumulation. Chemically, physically, and biologically septic tank sludge is a highly variable material. Its properties are influenced by the design of the septic tank system, frequency of pumping and the septic tank system application for domestic, industrial or commercial areas.

The collection, treatment and disposal of septic tank sludge in the United States has received only a passing attention from Environmental Quality Control engineers and scientists (Bennett et al. 1975). The satisfactory operation of septic tank depends, in part, on the periodic removal of the accumulated particulate materials from the tank. The frequency of sludge removal as recommended by various regulatory agencies varies from one to five years, with most agencies suggesting three years as desirable accumulation period (U.S.P.H.S. 1967).

Septic tank sludge offers disposal problems because of its offensive appearance, has a foul odor upon exposure to the air, and contains many bacteria and viruses.

The three basic methods of treatment include land disposal, treatment at sewage treatment facilities and separate septage treatment at physical-chemical treatment plant. Detailed evaluation of treatment methodologies is beyond the scope of this report.

CHAPTER IV

OPERATING PROBLEMS AND SOLUTIONS FOR ON-SITE TREATMENT SYSTEMS

Septic Tank Operation and Maintenance

One of the major advantages of the septic tank is that it has no moving parts and, therefore, needs very little routine maintenance. A well designed and maintained concrete, fiberglass or plastic tank should last for 50 years. Because of corrosion problems, steel tanks can be expected to last no more than 10 years (Brandes (1980). One cause of septic tank problems involves a failure to pump out the sludge solids when required. As the sludge depth increases, the effective liquid volume and detention time decreases. As this occurs, sludge scouring increases, treatment efficiency falls off, and more solids escape through the outlet.

Recommended maintenance for the septic tank should include:

1. Annual inspection to see that scum build-up is not excessive enough to pass the skimmers and sludge is no more than 2 feet deep.

2. Scum and sludge should be removed when the sludge depth exceeds 2 feet. At least six inches of sludge should remain in the bottom of the tank for seed purposes, to insure continuation of the tank's biological balance for continuous proper treatment of the effluent.

Dilutions Disposal Method

There are several types of disposal systems in general use in West Africa. This system of disposal is not recommended unless in a strict lack of alternatives. Where large bodies of surface water, such as the sea, large rivers, are available nearby, the liquid waste from the dwellings or after septic tank treatment may be discharged to a point well below the lowest water or sea level, preferably near the bottom of the receiving water which will normally rise and disperse through the mixing and dilutional ability of the water body.

The 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. The danger and disadvantage is the creation of anaerobic conditions due to exhaustion of oxygen, thereby upsetting the biological balance of the water. And also the possibility of contaminating the water with pathogenic bacteria and the eggs and larval forms of harmful helminths. Wagner and Lanoix (1958) recommend that in this case for natural waters, the amount of sewage should not be more than one-twentieth to one-fourth of the amount of water flowing.

Seepage Pit

This is another disposal method requiring a deep groundwater table (in excess of thirty feet) and a deep pervious strata above the water table. The installation usually consists of a large diameter (30 inches or more) deep bore (more than 30 feet) hole that is filled with stones or cased to support the wall. Because of the depth, it introduces anaerobic effluent with anaerobic ground conditions, loosening the purification properties of the desired aerobic absorption media. This system can easily plug if continuously inundated. There is also the danger of groundwater pollution, therefore Wagner and Lanoix (1958) recommend for areas in West Africa that seepage pits be located downhill, and in any case, at least 50 feet away from drinking water sources and wells.

Cesspools

This is a covered large diameter (5-6 feet) sump often filled with stones to give support to the sidewalls. This installation generally serves as both septic tank and percolation system, receiving raw sewage or effluent directly from the plumbing fixtures. It is not usually environmentally acceptable since the installation is of very simple design with no capability for skimming floating matter. This system is widely used in many West African suburbs; but their construction is not permitted by health authorities in densely inhabited communities where wells are used as sources of drinking-water supply.

Cesspools are almost completely ineffective as an absorption system in sandy or silty soils and plugging is very rapid since both side walls and bottom are continuously covered with raw sewage or wastewater. Wagner and Lanoix (1958) recommend that for a situation where it is desperately required that cesspools should be used, it should be located downhill from a well; in any case, a distance of 50 feet will prevent bacterial pollution of the well; and to prevent chemical pollution, it should be 150 feet away from a well uphill from it.

Evaporation System

Two basic types of evaporation systems are presently in use in the United States:

1. Evapotranspiration beds (with or without infiltration)
2. Lagoons (with or without infiltration)

The evapotranspiration implies evaporation and transpiration. The evaporation is based on the sun's ability to cause the water to vaporize. The transpiration is based on the advantage of reducing the water by vegetation on and around the bed that transports water through the roots to the leaves where it is transpired.

The evapotranspiration system is used in an arid climate where soil properties preclude trench absorption systems, and have the advantage of utilizing the natural energy of the sun and, optionally the natural purification capabilities of soil to dispose of the wastewater. The evapotranspiration (ET) bed normally consists of an impermeable liner and wastewater distribution pipe, while in the modified system the evapotranspiration/absorption (ETA) the impervious liner is omitted and a portion of the wastewater is disposed of by seepage into the soil. Both systems operate by discharging effluent into a pit with impervious (ET) or pervious (ETA) lining filled with selected size sand, small enough to allow water to rise by capillary action and large enough to provide sufficient flow capacity to handle the output of the residence. Bennett, Linstedt and Felton (1980) recommend sand in D_{50} size range of 0.12-0.18 mm with uniformity coefficient of four or less as desirable. The selected sand is laid over a 9-12 inch bed of gravel overlying a 2 inch sand layer next to the impervious (ET) or pervious (ETA) membrane. No serious problems have been reported on this installation in use at Lagos, Nigeria, as reported by Olunwande (1975).

Knowledge of Percolating Systems

Some methods to determine acceptable soils and how to maintain satisfactory operation of soil absorption systems was outlined by McGauhey (1975) as:

1. The standard percolation test can measure the infiltrative capacity of a soil initially and identify a potentially feasible soil for percolation. It cannot predict a future overlying

zone of clogging. If the test is used for determining size by interpretation of the results, the bottom area may be inadequate because the test was originally designed for narrow trench use.

2. A soil, saturated with even clear fresh water, will clog because the aerobic bacteria with the organic matter already in the soil are deprived of oxygen when the pore spaces are filled with water. The system then becomes anaerobic and clogs with bacterial slime and precipitation.

3. A soil that is continuously inundated will lose most of its initial infiltrative capacity. A system sized on initial rather than maintainable infiltrative capacity is liable to fail.

4. Water will not absorb enough oxygen to maintain an aerobic system in inundated soil. The soil must be allowed to drain, the pore spaces refill with air and the aerobic bacteria to reestablish their life cycle.

5. The clogging of the soil is a surface phenomenon of the top 0.5-1.0 centimeters, resulting from anaerobic slimes precipitation of ferrous sulfide and sedimentation. Clogging may be overcome by proper operating procedures, including alternate loading and resting of the soil.

McGauhey (1975) further stressed that regardless of the type of absorption system selected, several operating parameters to aid in extending the service life of an absorption system include:

1. Avoid continuous overflow of the infiltrative surface.

2. Maintain aerobic conditions in the soil.

3. The initial infiltrative surface should be as close to an undisturbed place of the soil as possible.

4. The entire infiltrative surface should be simultaneously loaded uniformly.

5. There should be no abrupt change in particle size between trench fill material, which is rock, and soil at the infiltrative surface.

6. The leaching field should provide a maximum of side-wall and minimum of bottom area per unit volume of effluent.

7. The amount of suspended solids and nutrients in the septic tank effluent should be minimized.

The environmental consequences of failures in septic tank percolation systems vary with situation and result in undesirable conditions. Failure may occur in a subdivision with owners piping or ditching effluent into the streets and with attendant health hazards, foul odors, and nuisance. Water supplies are not usually affected because the systems are separate.

In villages and isolated areas, groundwater supplies used for drinking water may be bacterially or virally polluted. However, a properly operated septic tank system results in minimal environmental changes. The dissolved mineral content of groundwater is almost always increased. Viruses almost always are added, although the quantity is held very low, and bacterial content usually increases, but within acceptable public health standards. Although it is still under experimental observation, there is hope it will fulfill the desired goal.

Trench Systems

The narrow and wide (bed) trench systems are the most commonly used method for individual wastewater treatment and disposal at most West African urban areas. John Pickford (1979) reports that the narrow trench is usually more acceptable. The trench is dug 12-36 inches wide and to a depth of at least two to four feet above the groundwater table that may be reported during the rainy season. Because of the fine weather (no freezing) in these areas in West Africa, the trench is usually installed in the aerobic biologically active portion of the top soil. Perforated four inch or larger drain pipes are laid in a bed of pea gravel or crushed rock, as shown in Figure 11 , and trenches are six to eight feet minimum separation.

Some operation problems are caused by clogging of the porous surface because of continuous inundation (overflow of wastewater). Poor construction practices, such as consolidation of the trench side-walls and bottom by mechanical equipment or human traffic, result in premature failure of the absorption system. Inadequate field size and installation in improper soils cause operational problems. Table 5 provides recommended rates of wastewater application for the trench in relation to the soil texture.

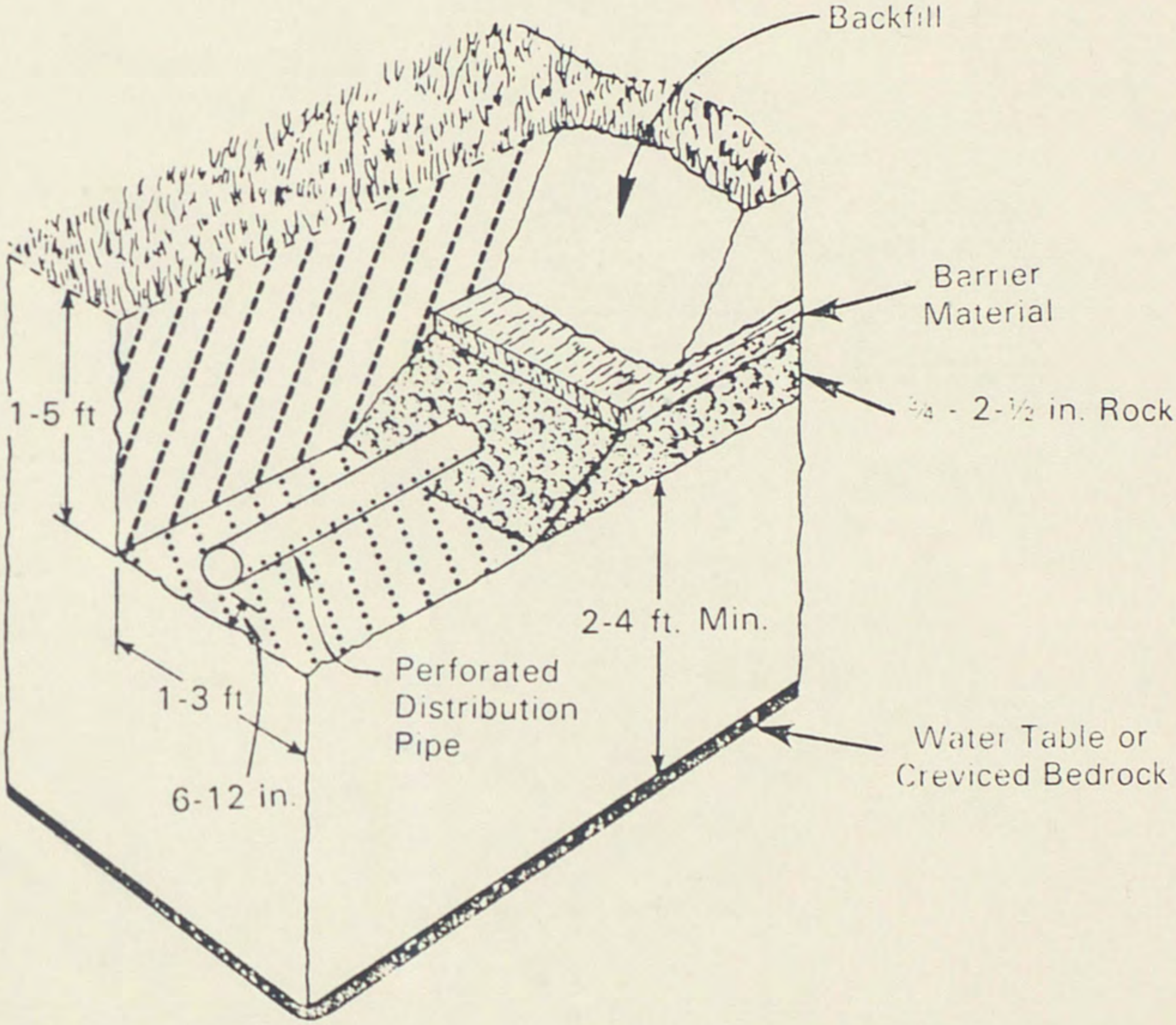


Fig. 11. Typical trench system.

TABLE 5

RECOMMENDED RATES OF WASTEWATER APPLICATION
FOR TRENCH AND BED BOTTOM AREAS (4)(11)(12)[a]

Soil Texture	Percolation Rate (min/in)	Application Rate (gpd/ft^2)
Gravel, coarse sand	< 1	Not suitable
Coarse to medium sand	1 - 5	1.2
Fine sand, loamy sand	6 - 15	0.8
Sandy loam, loam	16 - 30	0.6
Loam, porous silt loam	31 - 60	0.45
Silty clay loam, clay loam[d]	61 - 120	0.2[e]

[a] May be suitable estimates for side-wall infiltration rates

[b] Rates based on septic tank effluent from a domestic waste source. A factor of safety may be desirable for wastes of significantly different character

[c] Soils with percolation rates <1 min/in can be used if the soil is replaced with a suitably thick (>2 ft) layer of loamy sand or sand

[d] Soils without expandable clays

[e] These soils may be easily damaged during construction

SOURCE: Jones, E.E. "Septic Tank Configuration Versus Performance," in On-site Wastewater Treatment and Disposal Systems, p. 98, EPA Design Manual, 1980.

CHAPTER V

ALTERNATIVE SYSTEMS

Methods for wastewater or excreta disposal are always required as an alternate means when natural conditions are not very conducive to existing standard methods.

Some of the conditions in Nigeria which are applicable to most West African countries that require alternate systems to the existing systems, as outlined by Olunwande (1975) are:

1. At the south, the water table is very close to the surface and rainfall is prevalent throughout the year at the most southerly part of the country.

2. The soil condition in some areas at the east and western portions of the country are not very acceptable for efficient effluent absorption.

3. At the north, the soil conditions favor transmission of effluent directly to the ground.

4. Generally at the central states of the country, the surface water level varies and is close to the ground level.

5. Existing septic tank effluents display rapid plugging even for suitable soil conditions.

It is required for health purposes that all homes in unserved areas must have a safe and effective means of wastewater or excreta disposal; however, the septic tank-soil absorption system cannot serve some of the homes because of unfavorable conditions, like soil and high water table. There is a wide variety of options as shown in Figure 12. Some of the alternatives to be discussed are the aerobic treatment units, disposal system by mound and the clivus multrium waste compost.

The Multrium Waste Compost

One of the main reasons for water pollution from the household is the fact that we use water as a transport medium for dissolvable materials such as toilet wastes, food waste, detergent, etc. Consequently, the most effective and logical way to decrease water pollution is to eliminate wastewater transport if possible (Lindstorm 1975).

If the organic matter now disposed of as a solid waste (soiled paper, garbage) is mixed with toilet wastes, the conditions for composting processes are almost ideal. Heat production and moisture in the material are favorable as well as the balance between carbon, nitrogen and phosphorus. The end product is a fertilizer containing trace metals such as sodium, iron, zinc, magnesium, etc., in addition to the normal nitrogen closely resembling the end product of a plant composting operation in both odor and texture. The chemical composition of the product closely resembles chemical fertilizer in content of potassium, nitrogen, phosphorus, magnesium and calcium.

If water consuming articles in the house are separated (shower, lavatory, sink and laundry) from the solid organic wastes

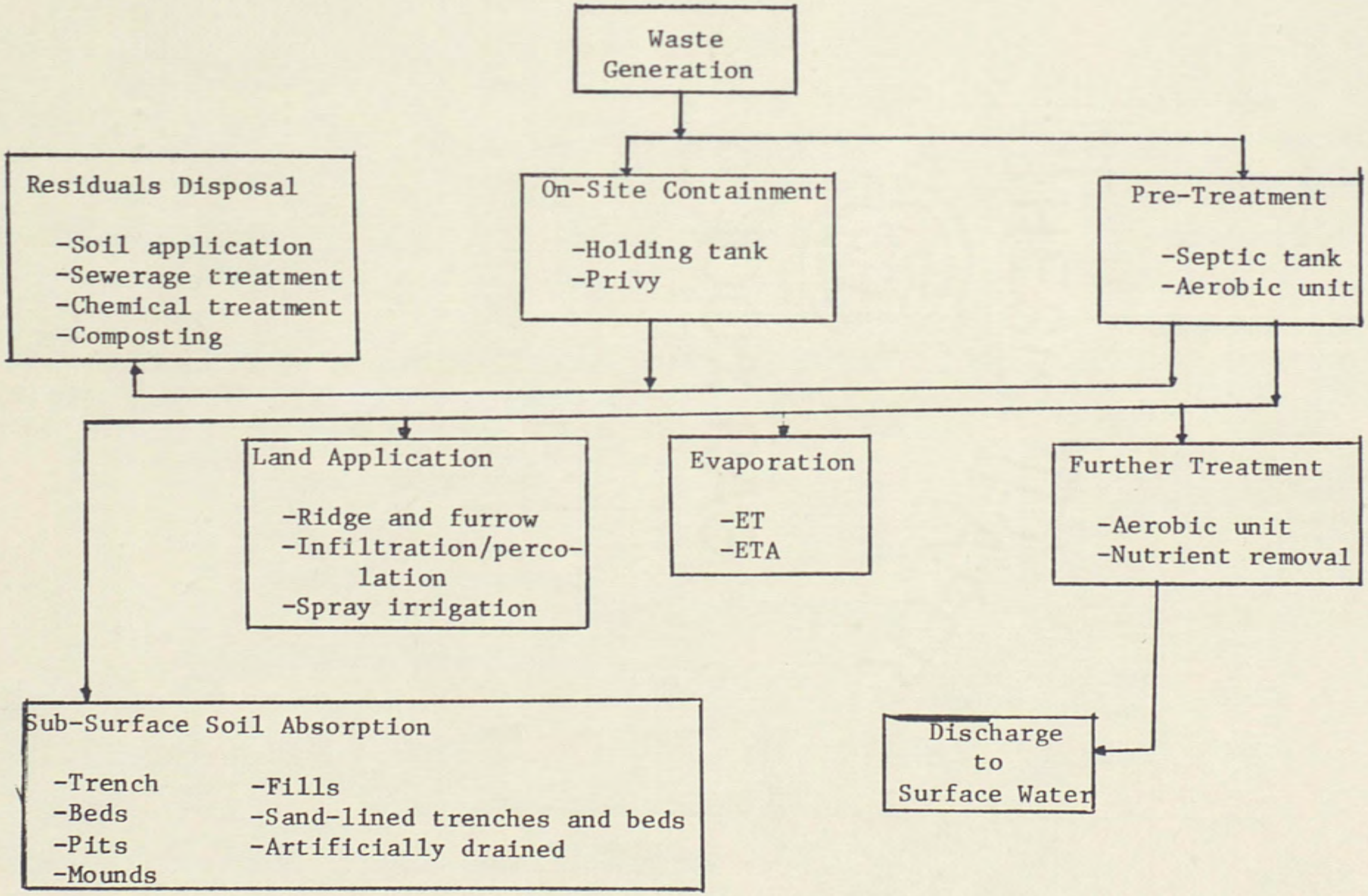
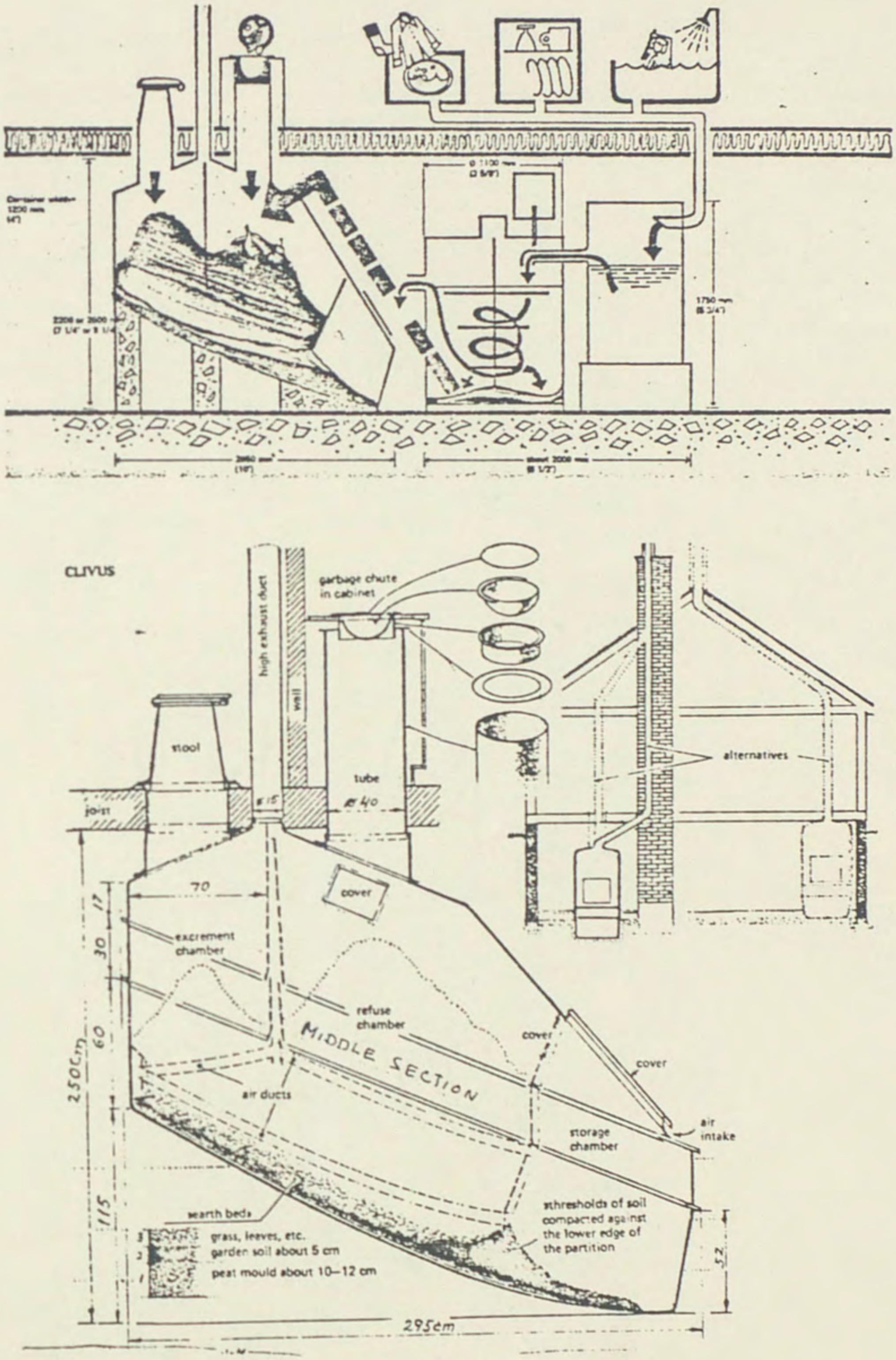


Fig. 12. Wastewater or excreta disposal options.

generated as garbage, toilet waste, and organic trash, paper; disposal and purification of the water is simplified and the environmental impact on groundwater is lessened. A simple solid infiltration may be effective, and the most that would be required is chemical precipitation and chlorination.

The major new item in this process is the composting equipment. The clivus compost reactor works on the principles of gravity, capillary action, and a special ventilation system. The composting material is enclosed in an impervious container as shown in Figure 13a and 13b. This container is connected to the toilet and kitchen refuse openings by means of two chutes. A vent allows the gases produced in the process to escape. A layer of topsoil placed on the sloping bottom contains the bacteria necessary for the decomposition of the toilet and kitchen wastes. The feces which accumulate in the upper chamber (on the left) also contain bacteria necessary to achieve aerobic decomposition. The urine is drained off down the sloping bottom to be decomposed by nitrobacteria existing in the soil, thus forming nitrate and carbon dioxide. (This is the same method or process by which urine deposited on the soil in nature is decomposed.) As the urine drains out of the excrement chamber, air is able to reach the oxygen-consuming organisms that break down feces. As the material decomposes, carbon dioxide (CO_2) and water vapor leave the container through the vent and the volume decreases simultaneously. As the kitchen refuse decomposes,



Figs. 13 a and b. The impervious clivus container.

SOURCE: Lindstrom, Carl R. "The Clivus-Multrium System: Composting of Toilet Waste, Food Waste and Sludge Within the Household," in Water Pollution Control in Low Density Areas. pp. 429-444. Edited by William J. Jewell and Rita Swan. Hanover, NH: University Press of New England, 1975.

the high proportion of cellulose present in this material produces heat which helps to evaporate the liquids, thus further reducing the volume.

Because the inside of the converter is kept at a lower pressure than the outside, there is no odor in either the bathroom or in the kitchen, both of which are actively ventilated when the covers are opened.

The process is broken into two stages or phases: the breaking down of the larger particles which generates the most heat and fairly rapid is measured in days, and the mineralization of the materials which takes place in months or years.

There was no mention of the presence of E. Coli bacteria in the end product, neither was anything said about viral presence by Lindstrom (1975).

The only mechanical device is the exhaust fan and sludge pump, if used. After composting, about ten gallons per person per year of soil is produced. The process is aerobic which does not emit offensive odors as a result of the process. The humus makes inorganic nutrients available to plants through direct uptake. The material in the reactor is almost completely mineralized and can supply only so-called earth bacteria, which also consumes most pathogens. The composter is practically failsafe as reported by Lindstrom (1975) because:

1. the unit has no mechanical turning or stirring

2. the "turn-over" speed is very low - it takes approximately two to three years for solid particles to turn through the reactor

3. the construction makes it almost impossible to take out material which is not mineralized

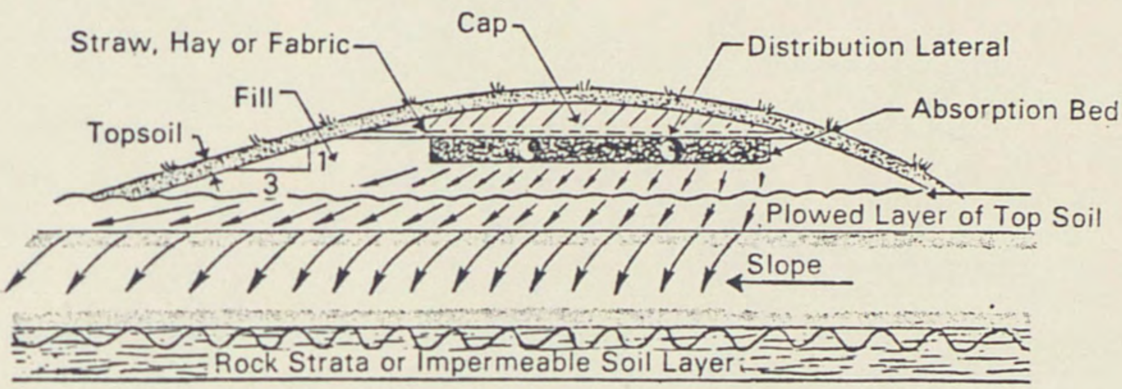
Because of the nature of this process, it certainly deserves further consideration and fits as a disposal system for the underdeveloped nations, especially a developing country like Nigeria.

Mound Absorption System

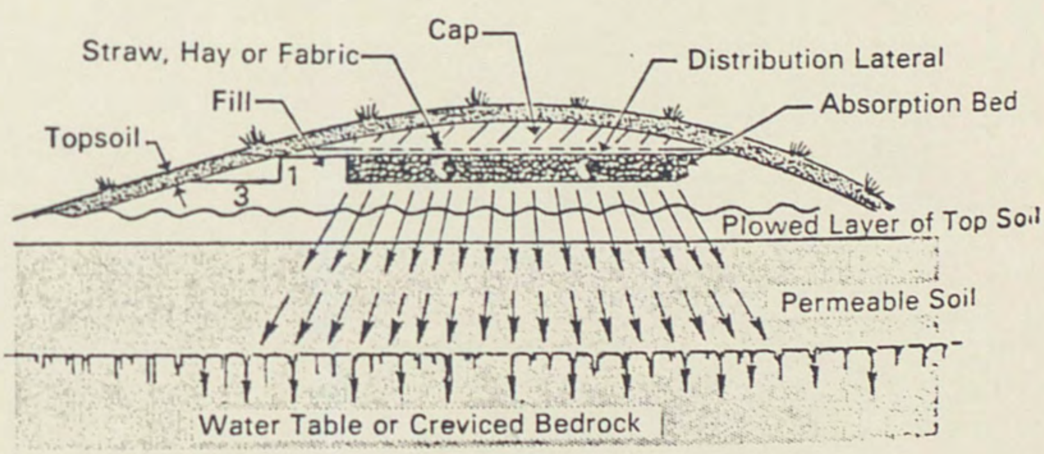
The mound system is a soil absorption system that is elevated above the natural soil surface in a suitable fill material. The purpose of the design is to overcome site restrictions that prohibit the use of convectional soil absorption system. Such restrictions are: (1) slowly permeable soils, (2) shallow permeable soils over creviced or porous bedrock, and (3) permeable soils with high water tables. In slowly permeable soils, the mound serves to improve absorption of the effluent by utilizing the more permeable top soil and eliminating construction in the wetter and more slowly permeable top soil, where smearing and compaction are often unavoidable. In permeable soils with insufficient depth to ground water or creviced or porous bedrock, the fill material in the mound provides the necessary treatment of the wastewater as shown in Figure 14.

The mound system consists of:

1. a suitable fill material



(a) Cross Section of a Mound System for Slowly Permeable Soil on a Sloping Site.



(b) Cross Section of a Mound System for a Permeable Soil, with High Groundwater or Shallow Creviced Bedrock .

Fig. 14. Typical mound systems.

2. an absorption area

3. a distribution network

4. a cap

5. top soil (see Figure 15)

The effluent is pumped or siphoned into the absorption area through a distribution network located in the upper part of the coarse aggregate. It passes through the aggregate and infiltrates the fill material zone where the treatment of the wastewater occurs. The cap which is a finer textured material than the fill provides frost protection, sheds precipitation and retains moisture for a good vegetative cover. The top soil provides a growth medium for the vegetation.

EPA (1980) provides site criteria for mound systems as summarized in Table 6 and Table 7, provides the commonly used fill materials and their design infiltration rates.

Aerobic Treatment Units with Surface Discharge or Discharge with Leaching Fields

The aerobic treatment units have been proposed for applications where septic leaching fields are deemed unsuitable. The aerobic treatment tank is shown in Figure 16. The tank discharges first into a disinfecting tank, then into a disposal field as desired. There are two main types of the aerobic treatment units, the continuous feed and the batch feed treatment units. Both are similar except that in the batch feed treatment unit, quiescent conditions during settling results in slightly better performance;

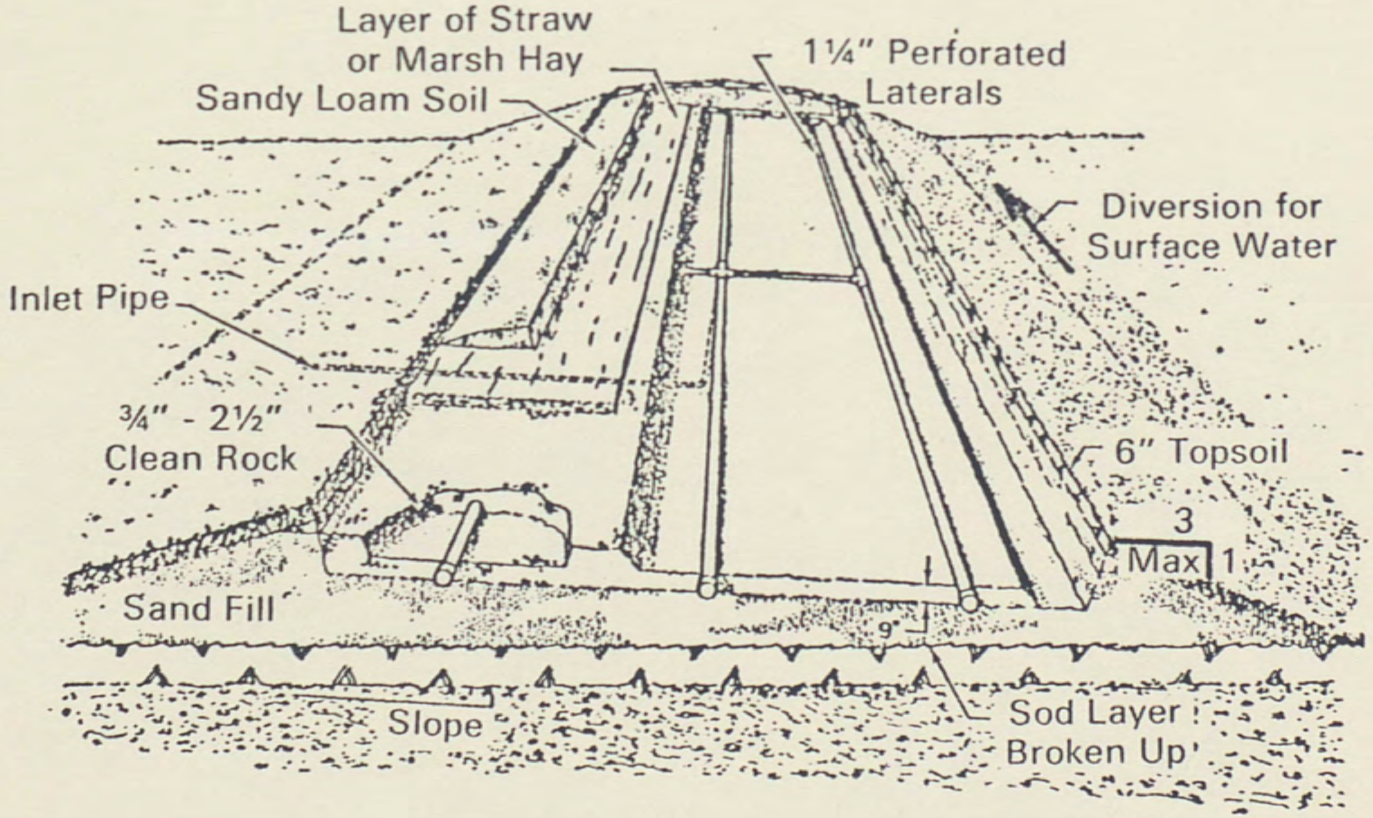


Fig. 15. Detailed schematic of a mound system.

TABLE 6

SITE CRITERIA FOR MOUND SYSTEMS

Item	Criteria
Landscape Position	Well drained areas, level or sloping. Crests of slopes or convex slopes most desirable. Avoid depressions, bases of slopes and concave slopes unless suitable drainage is provided.
Slope	0 to 6% for soils with percolation rates slower than 60 min/in.[a]
Typical Horizontal Separation Distances from Edge of Basal Area	
-Water Supply Wells	50 to 100 feet
-Surface Waters, Spring	50 to 100 feet
-Escarpments	10 to 20 feet
-Boundary of property	5 to 10 feet
-Building Foundations	10 to 20 feet (30 feet when located upslope from a building in slowly permeable soils).
Soil	
-Profile description	Soils with a well developed and relatively undisturbed A horizon (topsoil) are preferable. Old filled areas should be carefully investigated for abrupt textural changes that would affect water movement. Newly filled areas should be avoided until proper settlement occurs.
-Unsaturated Depth	20 to 24 in. of unsaturated soil should exist between the original soil surface and seasonally saturated horizons or pervious or creviced bedrock.

TABLE 6 (Continued)

Depth to Impermeable Barrier	3 to 5 feet[b]
Percolation Rate	0 to 120 min/in. measured at 12 to 20 in.[c]

[a] These are present limits used in Wisconsin established to coincide with slope classes used by the Soil Conservation Service in soil mapping. Mounds have been sited on slopes greater than these, but experience is limited.

[b] Acceptable depth is site dependent.

[c] Tests are run at 20 in. unless water table is at 20 in., in which case test is run at 16 in. In shallow soils over pervious or creviced bedrock, tests are run at 12 in.

TABLE 7

COMMONLY USED FILL MATERIALS AND THEIR DESIGN INFILTRATION RATES

Fill Material	Characteristics		Design Infiltration Rate (gpd/ft²)
Medium Sand	>25% <30-35% <5-10%	0.25-2.0 mm 0.05-0.25 mm 0.002-0.05 mm	1.2
Sandy Loam	5-15%	Clay Content	0.6
Sand/Sandy Loam Misture	88-93% 7-12%	Sand Finer Grained Material	1.2
Bottom Ash	---------		1.2

[a] Percent by weight.

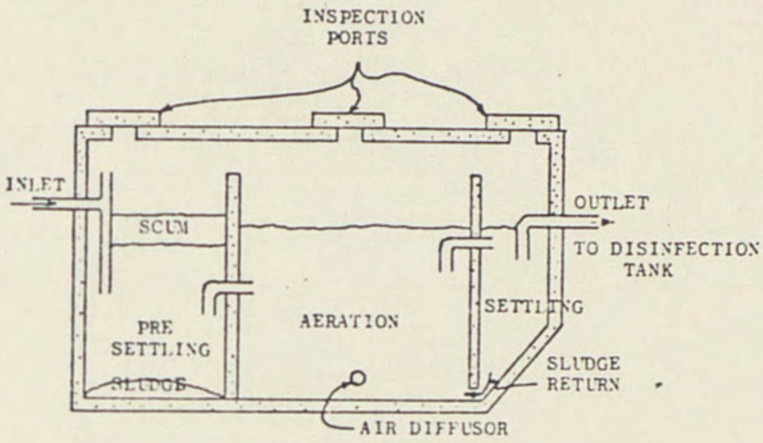


Fig. 16. Typical aerobic unit.

the treatment capacity is about 450 gallons and compressed air is fed in an 18 hour cycle which shuts off in the early morning to allow the solid to settle. Because of the size of the tank, some form of holding tank is required to assure treatment time for the whole 450 gallons.

The continuous aerobic tank is a small package sewage treatment unit that functions in a manner similar to a small extended aeration activated sludge treatment plant. The construction materials may be metal, prefabricated fiberglass, or concrete. Metal tanks are subject to corrosion. The cheaper of the materials is concrete.

Aeration is generally provided with compressed air and aided by mechanical stirring. The design detention time in the aeration chamber is in the range of one to two days. Bennett (1975) in his investigation found that aerobic treatment tank operation was affected adversely by normal househole wastewater surge (swell) flows and the rormal lack of maintenance by the home owner. In many instances, it was found that the suspended solids in the effluent were about the same as in the aeration chamber. This adversely affected the chlorination of the effluent because the chlorinator was not responsive to the surge.

Otis et al. (1975) reported the same findings in the variation in effluent with surge flows, and states that under more precise controlled conditions, the BOD_5 was significantly lower than the usual septic tank output (approximately 30 mg/l vs. 110 mg/l).

Bennett (1975) indicated in his data a cost of approximately $5.05/1000 gallons for aerobic treatment and $0.90/1000 gallons for septic tanks. The size of tank used for a normal residential family is about 1200 gallons.

Both the continuous and batch require regular maintenance of bi-monthly inspection and floating sludge removal. Some of the problems are mechanical problems, and floating grease that causes plugging.

Cost

There is no available report on the cost of septic tank and cost of treatment from any nation in West Africa; but from the literature review, Olunwande (1975) gave an approximate estimated ratio of 1 to 1.9 as the cost in U.S. to Nigeria. That implies that if septic tank capital cost is $200, it would be $380 in Nigeria.

Bennett (1975) gave a typical cost range for septic tank systems as shown in Table 8, and Table 9 for the treatment cost of aerobic systems

TABLE 8

TREATMENT COST - SEPTIC TANK SYSTEM
FOR 20 YEAR LIFE, COST OF TANK = $370

Soil Permeability	Ft^2 Absorption Area Required 4 Bedroom	Absorption Field Costs	Total Annual Cost	Total Annual Cost/ 1000 gal.
Good	280	$ 300- 450	$ 80	$0.90
Fair	500	$ 500- 750	$100	$1.15
Poor	1330	$1330-2000	$200	$2.20

Cleaning cost $15/year

Capital recovery at 20 yr. and $7\frac{1}{2}$% interest rate

TABLE 9

TREATMENT COSTS OF AEROBIC SYSTEMS

	Annual Cost $/yr.	$/1000 gal.
Purchase and installation $1000-1600		
Amortization	100-160	$1.40
Electricity	25-100	0.70
Service	30- 50	0.50
	155-310	$2.60
Disinfection initial cost $150-250		
Amortization	15- 25	$0.25
Chemicals and maintenance	20- 50	0.40
	35-110	$0.65
Subsurface filter $350-500		
Amortization	35- 50	$0.50
Operation	5- 15	0.20
	40- 65	$0.70
Leach field $300-2000		
Amortization	30-170	$1.00
Operation	5- 15	0.15
	32-215	$1.15

Capital recovery in 20 years at 7 1/2% interest.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

This investigation and research for an area in West Africa or an area with similar climatic, vegetational and environmental conditions where there is no prospect of connection of wastewater to central sewerage system; but the desire is to prevent surface soil contamination, contamination of groundwater that may enter springs and wells, surface water contamination, handling of fresh excreta, odors or unsightly conditions from excreta, and to utilize a method of disposal that is simple and inexpensive in construction and operation. From the standpoint of capital investment, and cost of maintenance operations, the septic tank with the narrow trench type soil absorption field would meet the above requirements and most favorable than other existing and alternate systems for a suitable soil condition, such as mounds or evapotranspiration.

However, careful attention should be given to construction details, resting of soil-bed by alternating flow to more than one drain field, periodic inspection and maintenance of the system to increase the life of the system and the quality of the effluent treatment by natural soil processes.

For areas or locations where the drain field will not offer good treatment, some alternate method of effluent disposal must be selected as appropriate. The use of the aerobic unit as a treatment option has some disadvantages because of the mechanical process involved that could lead to mechanical failure, and it has an increased capital and maintenance cost over the septic tank as shown in Tables 8 and 9 in the previous chapter.

The Clivus Multrium Composting System is now gaining wide acceptance and may be the answer to the area in discussion because of the added benefit on septage disposal over the septic tank; and the reduction in transport water.

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