HUMAN WASTES DISPOSAL - ETHIOPIA:

A PRACTICAL APPROACH TO ENVIRONMENTAL HEALTH

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PREFACE

My earlier book, *Water Supply - Ethiopia: An Introduction to Environmental Health Practice* (Addis Ababa University Press), appeared in 1977. In that book a brief introduction was made to the development and scope of environmental health, and a comprehensive description was given of water supply, its sources, construction, protection techniques, treatment methods, quality control, distribution, etc.

This present book is a companion to that book and deals with an inter-related subject, namely, the problem of human excreta disposal. The book is arranged in seven parts:

CHAPTER ONE	deals with the importance of excreta-borne diseases in public, health work, with their classification and a brief explanation.
CHAPTER TWO	gives a brief description of the life-cycles of transmitters, methods of transmission and control measures of some of the more relevant excreta-borne diseases.
CHAPTER THREE	emphasizes the importance to public health of excreta-borne diseases in Ethiopia, the economic impact of excreta-borne diseases and the prevailing situation regarding the availability of excreta disposal facilities in the country.
CHAPTER FOUR	describes the objectives of human excreta disposal and the different methods which can be used for non-water carriage systems of excreta disposal.
CHAPTER FIVE	summarizes the principles and practices of water carriage systems of human excreta disposal.
CHAPTER SIX	gives brief details of individual sewage treatment and disposal systems.
CHAPTER SEVEN	deals with effluent.
CHAPTERS EIGHT AND NINE	deal generally and in more detail with municipal sewerage systems.

The book is written in as simple a way as possible, in order to orient decision-makers at all levels to the importance of human excreta disposal in social development management, and to provide an immediate source of reference for health workers and other cadres engaged in community development work, students of health sciences, and technical and other institutes of higher learning.

It is my earnest hope that this book and my previous book, *Water Supply - Ethiopia*, will together be of some value in the implementation of the International Drinking Water Supply and Sanitation Decade, launched in November 1981, and thus in force from 1981 to 1990.

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– Publishers George Allen and Unwin, and authors L. Goodwin and A.J. Duggan, *A New Tropical Hygiene*, 1964 (for life-cycles of the hookworm, roundworm, beef tapeworm and *Schistosoma*);

– Authors U. Winblad, W. Kilama and K. Torstensson, *Sanitation Without Water*, 1981 (for the Vietnamese double-vault latrine).

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INTRODUCTION

THE ROLE OF ENVIRONMENTAL HEALTH IN DISEASE PREVENTION AND CONTROL

Communicable diseases are diseases that can be transmitted from sick persons to healthy persons or from infected animals to healthy persons. They are caused by different forms of germs, living organisms, commonly called pathogenic organisms. Since mostpathogenic organisms are extremely small and are visible only through microscopes, they are often called *micro-organisms.* Pathogenic organisms can be multicellular helminths (worms), which are generally relatively large and are visible to the naked eye; or they can be single-celled micro-organisms, such as protozoa, bacteria, *Rickettsia* and viruses.

Communicable diseases can be classified in various ways. One way is on the basis of their modes of transmission, or channels of communication from one person to another, as follows:

1. Diseases transmitted through intestinal discharges (human excrement): ascariasis, amoebic and bacillary dysentery, typhoid and paratyphoid fevers, cholera, etc.
2. Diseases transmitted through the bite of arthropods (insects, etc., with jointed limbs): malaria, yellow fever, typhus fever, leishmaniasis, onchocerciasis, etc.
3. Diseases transmitted by airborne droplets (nose and throat discharges): the common cold, tuberculosis, influenza, etc.
4. Diseases transmitted to man from vertebrate animals (e.g. beef tapeworm when he eats infected meat, or rabies through a bite). Rabies and other similar diseases are known as *zoonotic diseases,* from *zoon* (Greek), an animal.
5. Sexually transmitted diseases transmitted through direct intimate contact and others transmitted by direct contact (e.g. some forms of leprosy).

For each category of disease listed above, there are specific preventive and control measures, based on our knowledge and the characteristics of the organisms causing the disease.

However, from the practical point of view, it is possible to devise a more general strategy to defend man from their invasion. The following are strategies, or lines of defence, against the major categories of disease:

1. Man's First Line of Defence against Disease is ENVIRONMENTAL HEALTH (SANITATION).

The provision of safe and adequate water supply; the proper disposal of human excreta and refuse; the control of safety of food, vegetables and beverages from disease-causing organisms or their poisonous products (toxins); the control of flies, lice, mosquitoes, etc.;

the keeping away of injurious substances from man's living and working environment - all these will block and prevent the disease-causing organisms from entering the human body. In other words, man's first strategy in fighting against diseases should be to ward them off before they get access to his body. This strategy falls mainly into the area of *environmental health* or *sanitation.*

By environmental health is meant the prevention of diseases and promotion of health by eliminating or controlling the factors surrounding man's life where those factors form links in the chain of disease transmission. For further information, see *Water Supply - Ethiopia: An Introduction to Environmental Health Practice*, by Gabre-Emanuel Teka (1977), Addis Ababa University Press, Addis Ababa. Like *Human Wastes Disposal - Ethiopia,* the previous work contains a glossary of relevant terms.

2. **Man's Second Line of Defence against Diseases is NUTRITION and PERSONAL HYGIENE.**

The human body is like a machine in that it requires energy for the maintenance of its normal functioning, as well as for the performance of work and other activities. The needed energy is derived from the digested and assimilated food that he eats. Therefore, the food that a person eats should be adequate in quality and quantity to provide him with all the body's essential needs. The practice of eating a balanced and adequate supply of food is called *nutrition.* Besides building and maintaining a strong body, proper nutrition enables man to be more resistant to the invading forces of disease-causing organisms. That is to say, the body's mechanisms of self-defence against the intruding organisms are strengthened, and this leads to the easy defeat of the enemy.

On the other hand, if the invaders enter a malnourished, weak body, they can easily overpower the body's defence mechanisms, and can cause disease.

In a similar manner, strict observation of the rules of *personal hygiene* can arrest the invading organisms before they can proceed into man's delicate internal organs. For example, a healthy, well-groomed and well-maintained skin, mucous membranes, sticky hairs inside the nose, wax in the ears, etc., can stop the entrance of harmful germs, and shut out the invading forces.

Personal hygiene includes all the things the individual person can do in order to maintain, protect and promote his or her health: the habits of eating a balanced diet, washing, taking exercise and recreation, rest and sleep, etc.

Furthermore, proper observation of personal hygiene helps to promote the body's defence mechanism against disease.

3. **Man's Third Line of Defence against Diseases is IMMUNIZATION.**

If the first and second lines of defence against disease are broken, and if the invading forces enter into the body itself, then whether the invaders succeed in causing disease, or not, will depend upon the body's reaction to the invaders.

In Public Health practice, the body may be armed in advance against some common diseases if and when their causative agents enter it. This practice is called *immunization,* the vaccination of individuals against certain diseases such as yellow fever, smallpox (now eradicated), measles, tetanus, whooping cough, poliomyelitis, diphtheria, etc.

At present, vaccination is available only for a limited number of diseases, and it cannot be applied to control or prevent all communicable diseases.

4. **Man's Fourth Line of Defence against Diseases is CURATIVE MEDICINE.**

Assuming that all the three lines of defence stated above fail, and a person gets sick, then treatment is the last line of defence against disease. *Curative medicine* is concerned primarily with the diagnosis (identification) and treatment of diseases. The science and art of curing the sick is a time-honoured practice that needs no further elaboration.

Usually, in Public Health Service, the four lines of defence against disease can be applied singly or in combination, depending upon the characteristics of the specific disease in question, and on the practicability of the line of defence to be used. In developing countries, poverty and shortage of water or food may all fight on the side of disease, but there are still methods which can be used against the dangers. Particularly the first line of defence, environmental health or sanitation, is practicable and can be used in almost any conditions of life.

It can be seen from this introduction that the role of environmental health in the prevention and control of disease, and indeed in the entire field of Public Health, is quite easy to understand. Its scope is wide and varied, and includes one of the most important fields - the treatment and safe disposal of human wastes. This is therefore the subject of this book.

CHAPTER ONE

THE IMPORTANCE OF EXCRETA DISPOSAL IN PUBLIC HEALTH WORK

The term *excreta* is applied to the waste matter (mainly faeces and urine) eliminated from the body. Disposal of excreta is an important part of environmental health work, because human excreta are the source of a large number of diseases transmitted through intestinal discharges. These diseases are known as *gastrointestinal diseases.*

In almost all parts of Ethiopia, as shown in many articles on health in, for example, the *Ethiopian Medical Journal* and other references given in Chapter Three of this book and elsewhere, gastrointestinal diseases rank first among the prevalent communicable diseases. Similar conditions prevail also in the majority of other developing countries, particularly in Africa, Asia and Latin America.

1.1 EXCRETA-BORNE OR FILTH-BORNE DISEASES

On the basis of the size and type of their causative agents, excreta-borne diseases may be classified into four groups.

GROUP I. HELMINTHIC OR METAZOAL DISEASES

The worms parasitic on humans and causing helminthic or metazoal diseases are divided into three large sections, each of which causes prevalent diseases passed on through human excreta: (A) roundworms or nematodes; (B) flatworms or cestodes; and (C) flukes or trematodes. The most important diseases caused by these parasites are shown below.

Disease	Causative agent
(A) Roundworms or nematodes	
1. Ascariasis	*Ascaris lumbricoides* (roundworm)
2. Trichuriasis	*Trichuris trichiura* (whipworm)
3. Ancylostomiasis	*Ancylostoma duodenale* (hookworm) *Necator americanus* (hookworm)
4. Strongyloidiasis	*Strongyloides stercoralis*
5. Enterobiasis (Oxyuriasis)	*Enterobius vermicularis*, *Oxyuris vermicularis* (pinworm, threadworm)
(B) Flatworms or cestodes	
6. Taeniasis	*Taenia saginata* (beef tapeworm) *Taenia solium* (pork tapeworm)
(C) Flukes or trematodes	
7. Bilharziasis (Schistosomiasis)	*Schistosoma mansoni* (causing intestinal bilharzia) *Schistosoma haematobium* (causing urinary bilharzia)

GROUP II. PROTOZOAL DISEASES

Disease	Causative agent
1. Amoebiasis	*Entamoeba histolytica*
2. Giardia (Lambliasis)	*Giardia lamblia*

GROUP III. BACTERIAL DISEASES

Disease	Causative agent
1. Typhoid and paratyphoid fevers	*Salmonella typhi* and *Salmonella paratyphi* A or B
2. Shigellosis (bacillary dysentery)	*Shigella* species
3. Cholera	*Vibrio cholerae*
4. Adult gastroenteritis without fever	*Salmonella* species other than *S. typhi* and *S. paratyphi*
5. Infantile gastroenteritis	Miscellaneous bacteria (e.g. *Escherichia coli*), but also protozoal and viral agents

GROUP IV. VIRAL DISEASES

Disease	Causative agent
1. Infectious hepatitis	Hepatitis-A virus (faecal-oral transmission; sometimes person-to-person)
2. Poliomyelitis	Polioviruses
3. Viral diarrhoea	Rotaviruses and others

The excreta-borne diseases listed above are sometimes known as *filth-borne diseases*, because the disease-causing micro-organisms reach man through food and water, fomites (articles which have been in contact with infection, and can transmit it), and soil, when these have been contaminated by faeces. Filth-borne diseases are also often called *fly-borne diseases*. The common housefly (*Musca domestica*) is very closely associated with human excrement and human foodstuff. Human faeces provide one of its favourite breeding-places. It can therefore easily spread the organisms of any gastrointestinal disease to foodstuffs carelessly exposed. People who eat the contaminated food are likely to develop the disease.

1.2 SOIL-BORNE DISEASES

In addition to the risk that humans, particularly children, may ingest contaminated soil from dirty hands, dropped plates or cups, or toys, the *soil* also plays an important role in the transmission of some excreta-borne diseases, in communities where open-field defaecation or faecal contamination of the ground is common. Under favourable environmental conditions caused by soil texture, vegetation, temperature and moisture, the soil provides protection for the development and spread of diseases such as ascariasis, trichuriasis and ancylostomiasis.

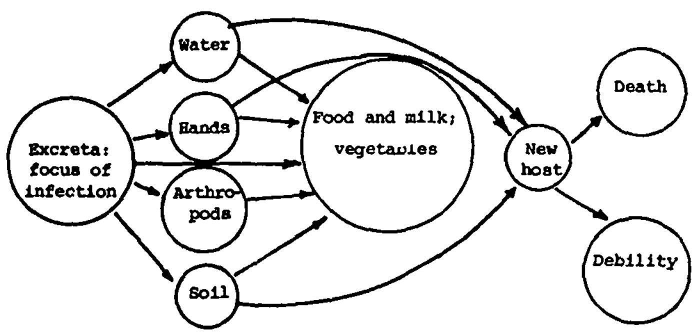
1.3 WATER-BORNE DISEASES

The most common of the *water-borne diseases* are typhoid and paratyphoid fevers, bacillary dysenteries, cholera, amoebiasis, and infections caused by intestinal parasites. The causative agents of all these diseases gain entrance into a water source from the faecal discharges of sufferers from the disease, or from healthy carriers of it. It is important to emphasize here that the micro-organisms causing the diseases do not grow or reproduce in water; in fact, they usually die off rapidly within a few days. However, water serves as a temporary habitat and as the medium of spreading these organisms from infected persons.

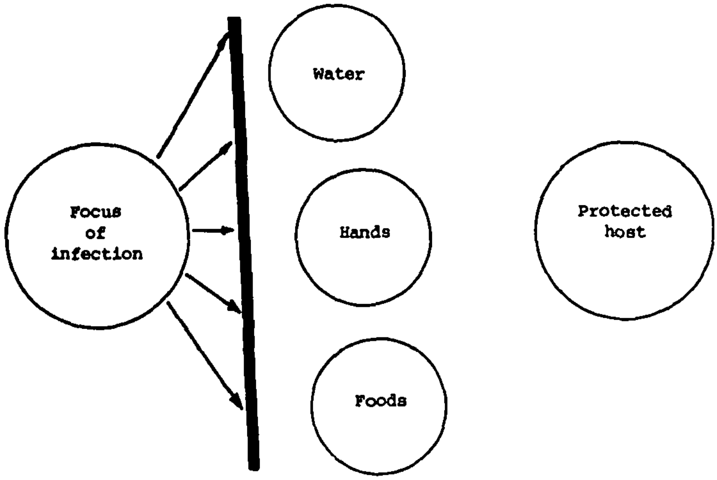
To summarize, a diagrammatic illustration of the mode of transmission of all excreta-borne diseases is shown in Figure 1a. Figure 1b shows that proper excreta disposal will to a great extent check the major water-borne and fly-borne diseases in Ethiopia, and prevent the spread of gastrointestinal diseases from one person to another.

FIGURE 1a and 1b. Transmission of disease from excreta

1a. Channels of transmission



1b. Stopping the transmission by means of sanitation



Adapted from W.H.O. Monograph Series No. 39, 1958 (Wagner, E.G., and Lanoix, J.N., *Excreta Disposal for Rural Areas and Small Communities*)

CHAPTER TWO

A DESCRIPTION OF SOME OF THE COMMON EXCRETA-BORNE DISEASES IN ETHIOPIA

A high incidence of enteric diseases associated with poor sanitation is characteristic of the disease picture in many of the developing countries of the world. The best ways of combatting these diseases, from the cost-benefit and cost-effectiveness point of view, are the provision of safe drinking-water, the practice of food hygiene, and the sanitary disposal of excreta.

S. Rajagopalan and M.A. Shiffman, *Guide to Simple Sanitary Measures for the Control of Enteric Disease*, p. 9. World Health Organization, Geneva, 1974.

2.1 ASCARIASIS (ROUNDWORM INFECTION)

Ascariasis is one of the common diseases, caused by a large roundworm with the scientific name of *Ascaris lumbricoides*, which is one of the commonest and most widespread of human parasites. Its distribution is worldwide, and it is particularly common in regions where the climate is hot and moist, and in communities where basic sanitation is lacking.

Life-cycle

The sexes are separate. The adult female worm usually ranges between 20 and 25 centimetres in length; the male varies between 15 and 20 cms. The worms live in the small intestine of man. They usually reach maturity in about two months. The females then lay eggs in the intestine of the human host; it is believed that a female *Ascaris* can lay up to 200,000 eggs daily, and its average lifespan is estimated to be between eight months and one year.

The eggs are deposited on the ground with the host's faeces. The eggs mature in the soil to become infective, and they produce a hard shell, which enables them to resist drying in the sun. These eggs, which are now called embryonated eggs, may reach the mouth of man through contaminated food or drink, and are subsequently ingested.

After being swallowed with food or water, the egg-shell is digested, and minute larvae are liberated in the host's stomach. The larvae penetrate the stomach walls and reach the liver and lungs through the lymphatic circulatory system. In the lung, they enter the air sacs (alveoli), travel up to the trachea, and are swallowed by the host for the second time. After this, they reach their goal - the small intestine - where they develop into adult worms and repeat the life-cycle (Figure 2).

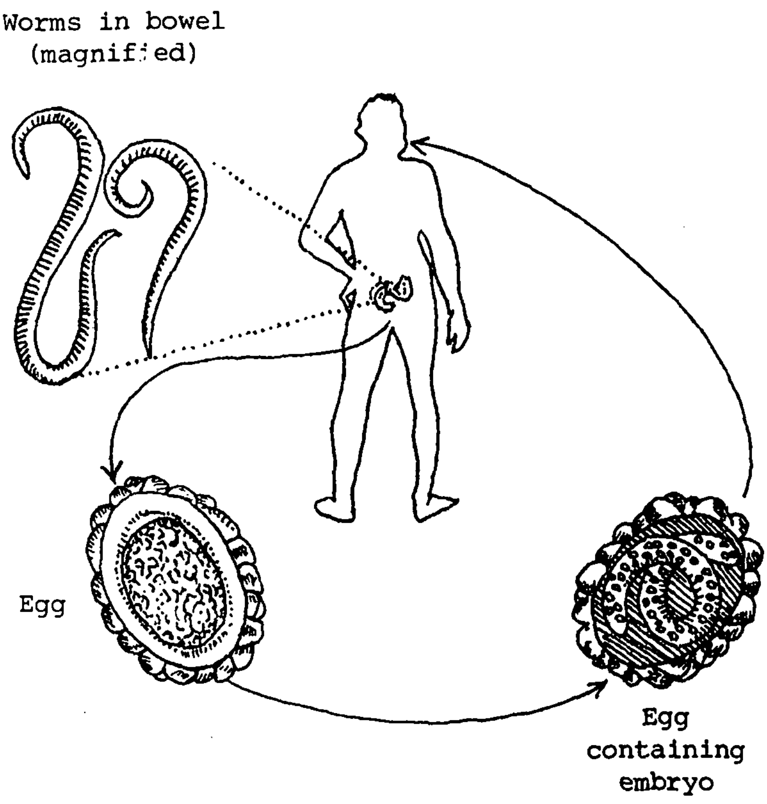
Ascariasis is common in all age-groups, but most common in pre-school and young children.

Since the life-cycle of *Ascaris lumbricoides* is a complicated one, its sequence is briefly summarized here:

1. Adult worms live in the small intestine of man.
2. Eggs are deposited with faeces.
3. Eggs mature and survive in the soil.
4. Embryonated eggs are ingested by a new host (man).
5. Eggs hatch into larvae in the stomach; the larvae enter the alveoli of the lungs, migrate via the trachea to the oesophagus, and are swallowed.

6. The larvae reach the small intestine, develop into adult worms, and repeat the life-cycle.

FIGURE 2. The life-cycle of the roundworm



Adapted from George Allen and Unwin, Ltd., *A New Tropical Hygiene*, by L. Goodwin and A.J. Duggan

Preventive measures

1. The most effective and lasting method of *Ascaris* control is the safe disposal of human excreta. By "safe disposal" is meant the prevention of contamination of topsoil (the earth on the surface of a field or other area) by human excrement. In

fact, human excreta must be isolated from man's total environment - from topsoil, water sources, all food and drink, flies, etc.

2a. The use of human excreta or sewage as fertilizer should be avoided for growing leafy green vegetables and root-vegetables which are normally eaten raw, without any cooking.

2b. The eating of uncooked vegetables should be avoided where human excreta are used as fertilizer.

3. Proper habits of defaecation must be taught to toddler-age children - children who are just learning to walk, who are more likely to contaminate the surface soil in the compound around houses. The washing of hands should be strictly practised before eating and after defaecating, as well as frequent baths or all-over washing after playing in contaminated soil or dust.

4. The elimination of worms from individuals through treatment is generally practised in Ethiopia. However, treatment *alone* will not succeed in interrupting transmission of a worm, unless the possibility of reinfection is also eliminated.

2.2 ANCYLOSTOMIASIS (HOOKWORM INFECTION)

Hookworm infection is a widespread disease in areas where the soil is a sandy clay, moist and covered with vegetation. In Ethiopia the disease is quite common in hot areas such as *qola* (from sea-level to 1,800 metres) and *weyne dega* (1,800 to 2,400 m), where the soil structure and climatic conditions agree with the above description.

Life-cycle

The adult worms live in the intestines of man. Here they produce eggs, which are passed out with faeces. If the eggs are deposited on a suitable place, where the soil is moist and warm, they hatch out into larvae in a few days, depending on the temperature. The larvae mature and remain on the soil until a human victim comes along. The larvae will penetrate any area of broken skin, or the soft tissue between the toes or fingers, and then enter the blood vessels. From there they are carried by the bloodstream to the air sacs of the lungs, travel to the trachea, and finally to the mouth, from which they are swallowed and reach their destination, the intestines. Here they stick to the intestinal walls, where they suck blood, mature and start producing eggs (Figure 3).

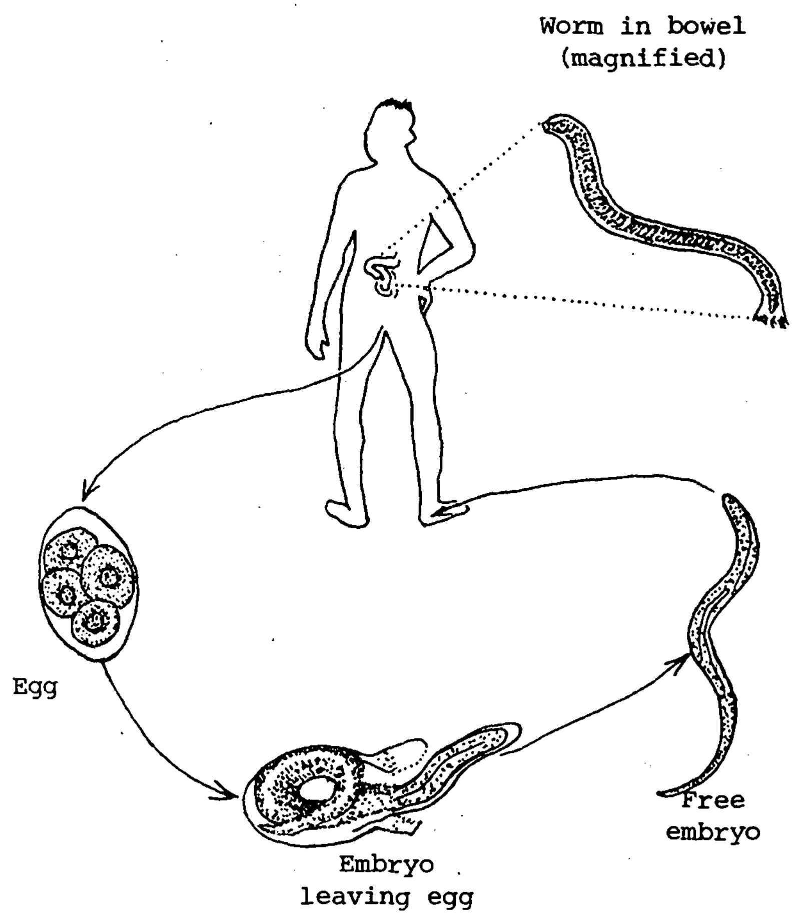
It is believed that the infective larvae can live over four months under favourable conditions. An infected person may harbour as many as 2000 or more parasites, and it has been estimated that a single hookworm sucks from its victim between 0.38 cc to 0.85 cc of blood daily. As a result, a victim of hookworm is often anaemic and malnourished. Hookworm infection is a common cause of what is called "iron deficiency anaemia" in Ethiopia.

Prevention of hookworm disease

1. As can be seen from the life-cycle, the first and foremost method of preventing this disease is proper disposal of excreta, so that the soil is not contaminated.
2. Shoes should be worn, and contact should be avoided between the bare skin of man and soil or grass, which is likely to harbour the larvae. This advice is not easy to follow, because it involves the habit of wearing shoes, a very costly habit, especially in rural communities.
3. Treatment can cure the victim of hookworm, but, in a community where open-field defaecation is practised and where barefoot walking is the custom, the rate of re-infestation is so high that the relief may be only a temporary measure.

4. Health education of the public must be provided, on how the disease is transmitted, how to provide an efficient excreta-disposal system, and how to use it properly.

FIGURE 3. The life-cycle of the hookworm



Adapted from George Allen and Unwin, Ltd., *A New Tropical Hygiene*, by L. Goodwin and A.J. Duggan

2.3 TAENIASIS (TAPEWORM INFECTION)

Everyone, from highest to lowest, has the beef tapeworm and takes the medicine for expulsion once every second or third month. They will not believe their practice of eating the meat of the cow raw has anything to do with it. They laugh heartily if you so instruct them, and go home to a good meal of raw beef. Stuart Bergsma, *Rainbow Empire*, p. 106. Wm. B. Erdmans Publishing Co., Grand Rapids, Michigan, U.S.A., 1932.

Beef tapeworm, scientifically called *Taenia saginata*, is one of the common large tapeworms infecting man. This tapeworm is called *kosso* in Amharic; the word *kosso* is used for both the parasite and the local remedy for it, an infusion of the female blossoms of the *kosso* tree, *Hagenia abyssinica*; *kosso* may also mean any local or imported medicine used to dispel the parasite. The tapeworm *kosso* is very familiar to many Ethiopians, who traditionally consume raw meat as *qurt siga* or *kitfo* (in slices or minced).

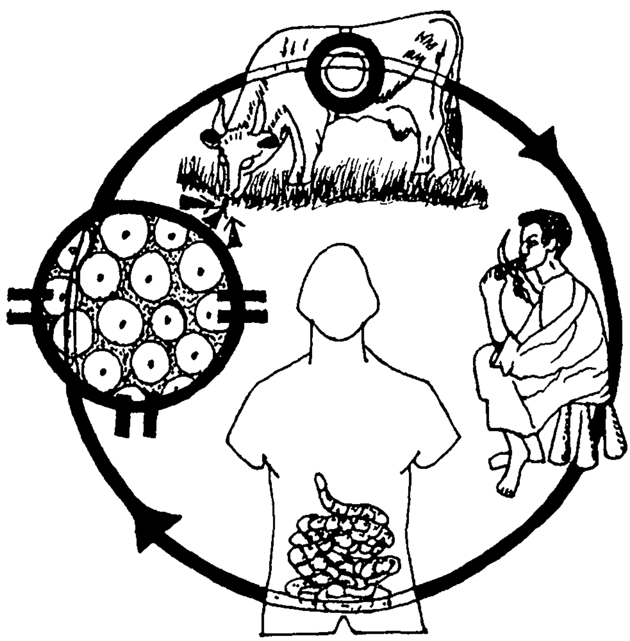
The tapeworm is made up of many segments or portions. The head, called the scolex, is small, and contains four cup-shaped suckers which enable the parasite to attach itself into the intestinal walls of the victim.

A fully-grown tapeworm varies from about 4 to 5 metres in length, and continually sheds off mature segments, which look like pieces of dirty tape or ribbon, and which contain eggs.

Life-cycle of the beef tapeworm

The life-cycle is indicated in Figure 4. The eggs are deposited with faeces. If defaecation is performed in an open field, or if sewage which contains the eggs contaminates grass where cattle graze, then the eggs are picked up by one of the cattle, and are swallowed with the grass. The eggs hatch in the animal's intestine, and larvae emerge. The larvae bore through the intestinal walls, enter the blood-stream and become lodged in the muscle tissues, where they develop a hard protective capsule. They then appear as cysts (called cysticircus bovis, "circular-shaped sac of the cow") in the meat of the animal.

FIGURE 4. The life-cycle of the beef tapeworm



Adapted from Oxford University Press, *Letters of Health*, by Ivy Pearce (1972)

When man eats raw or partly cooked meat, the capsule is digested, and either the scolex or a new tapeworm is set free in the intestine of man. As stated above, the head of a beef tapeworm has muscular suckers which enable the parasite to fasten itself to the intestinal walls of the victim. Here it grows and matures by absorbing the digested food of the host. The mature parasite continually sheds ripe segments which are filled with eggs, and these are deposited with the faeces.

Starting from the day the eggs are swallowed, it takes from two to three months for the parasite to produce ripe segments which contain eggs. As long as the scolex is fastened to the intestinal walls of the victim, new segments (*kosso*) will continually grow to replace those which are shed.

NOTE: (a) Infection with beef tapeworm (*Taenia saginata*) occurs only from eating the raw or uncooked or insufficiently cooked meat of a cow or an ox.
(b) Each segment of a tapeworm is a self-contained reproduction unit for the mature eggs.

Prevention of tapeworm infection

1. As can be seen from the life-cycle, the eggs are voided with the faeces of the infected person, and cattle are infected by grazing on the contaminated grass. Therefore, the ultimate prevention lies in proper excreta disposal.
2. Thorough, hygienic meat inspection is required, in order to ensure that the meat which reaches consumers is free from the cysts of tapeworm.
3. Meat must be cooked thoroughly: every part of the meat must be exposed to a minimum of 56°C heat before it is eaten, to kill the cysts. The traditional *kitfo* or *lebleb* (raw or slightly cooked minced meat) or any chunk of meat that is only partially roasted cannot be considered safe.
4. The eating of raw beef must be avoided. Yet we acknowledge that this control measure is unlikely to be successful in present-day Ethiopia, because of the long tradition of eating raw beef as one of the most popular national dishes.

2.4 SCHISTOSOMIASIS OR BILHARZIASIS

Schistosomiasis or bilharziasis is a disease which is caused by a blood fluke known as a trematode. The causative agents are the adult male and female worms living in pairs in the veins of the portal system - the blood vessels of the intestinal tract or urinary bladder vessels.

The schistosomes, as the worms are known, cause two main types of disease, depending on their location in the body:

(a) Intestinal schistosomiasis, caused by *Schistosoma mansoni* or *S. japonicum*;
(b) Urinary schistosomiasis, caused by *S. haematobium*.

The intestinal type is usually characterized by ulceration of the walls of the intestinal blood vessels, causing blood to be passed with the faeces. The urinary type of schistosomiasis is characterized by inflammation of the bladder, causing blood to be voided in the urine.

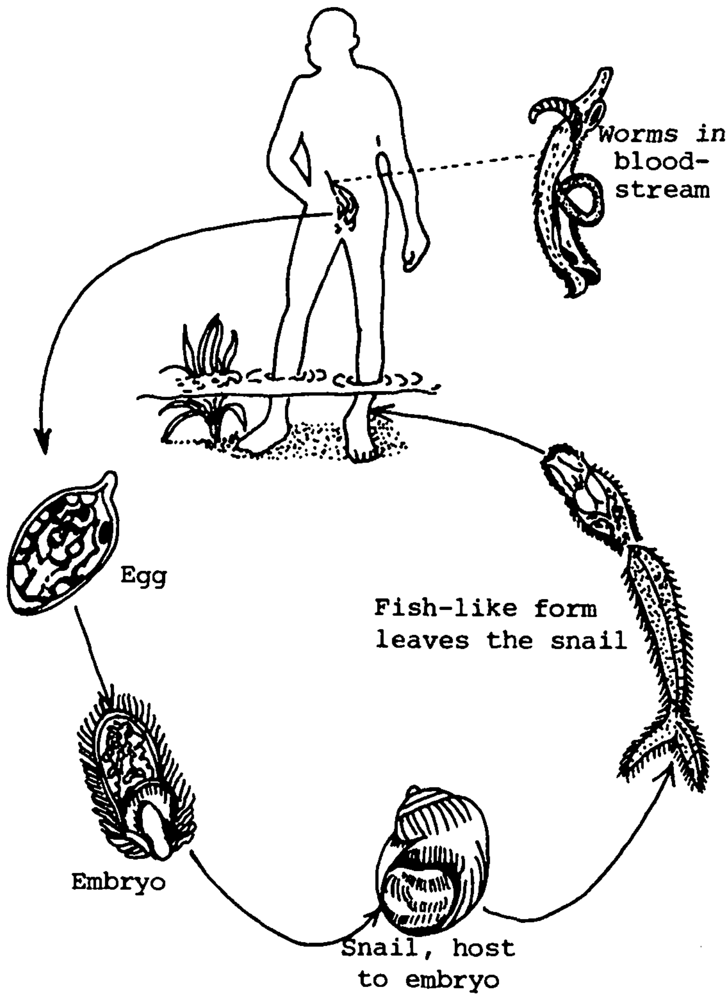
Life-cycle

The life-cycle is completed in two stages:

(a) Stage 1 takes place in man's blood vessels.
(b) Stage 2 takes place in a specific type of snail, which lives in shallow, slow-moving fresh water, such as slow streams, man-made channels for irrigation, and the edges of some lakes.

The worms live in the veins of the portal system, as stated above. The female worm is about 20 mm long, and lives in a groove on the undersurface of the thicker and shorter male (Figure 5). The pair of worms are carried by the bloodstream until they lodge in the appropriate place in the blood vessels. Once lodged, the female lays eggs, usually up to 100 in number. The eggs penetrate the walls of the intestinal or urinary tract, and are passed with faeces or urine, depending on the species.

FIGURE 5. The life-cycle of *Schistosoma*



Adapted from George Allen and Unwin, Ltd., *A New Tropical Hygiene*, by L. Goodwin and A.J. Duggan

If the faeces or urine reach water, the eggs hatch immediately in the water, and free-swimming larvae (miracidia) are liberated. The newly-emerged larvae must find and enter a suitable fresh-water snail within one or two days.

After entering the right type of snail host, the miracidia develop in the snail body into infective forms of larvae, known as cercariae, in several weeks.

The cercariae are discharged from the snail in large numbers: as many as 11,000 cercariae may be shed or cast out daily from a single snail. The cercariae have forked tails, and swim strongly in water. They must enter a human host within three days, otherwise they die off and the life-cycle is interrupted. If they find human skin within the right time, they burrow into and penetrate the skin, travel with the blood circulation, and finally reach their destination, the blood vessels of the intestine or urinary tract or bladder, from where the life-cycle is repeated (Figure 5).

It is important to note that humans get infected by schistosomiasis while collecting water, bathing, swimming, washing the body, washing clothes, wading or working in water. *Contact with water which contains the cercariae* is essential for the continuation of the disease.

The seriousness of the disease is closely related to the worm load in the victim, and is estimated by faecal and urinary egg counts. The prevalence and intensity of infection are higher in younger members of the population, and decrease by age.

Preventive measures

As can be seen from the life-cycle, there are three points where, theoretically, the chain of transmission of schistosomiasis can be broken:

1. Proper human excreta disposal will prevent faeces or urine containing viable *Schistosoma* eggs from reaching any body of water, whether a river, lake, irrigation ditch or any other water. The eggs cannot develop into larvae if they do not come into contact with water.
2. Contact with water containing the infective stage of the worm - the cercariae - should especially be avoided. But this advice is generally impracticable, because the use and habits of water contact are difficult to alter.
3. The intermediate host - the snail - may be eliminated or controlled. If the larvae (miracidia) do not find the specific type of fresh-water snail that they need, they will not develop into the infective stage as cercariae.

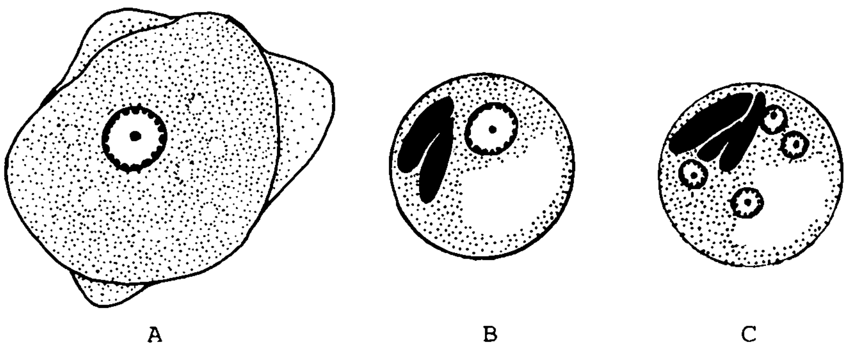
2.5 AMOEBIASIS (AMOEBIC DYSENTERY)

Amoebiasis, or amoebic dysentery, is a diarrhoeal disease caused by a protozoan organism called *Entamoeba histolytica. E. histolytica* lives in the intestinal tract of man and is found in two forms:

A. **The trophozoite (vegetative) form.** The trophozoites or vegetative forms are active, growing forms of the parasite. They are motile, feed actively, and undergo multiplication by what is known as binary fission (one becomes two, and two become four, and so on). Usually the trophozoites invade the tissues of the intestinal wall of the victim, causing bleeding. Accordingly the trophozoites are responsible for the characteristic acute stage of amoebiasis, with bloody diarrhoea.

B. **The cyst stage.** Subsequently, certain of the trophozoites stop feeding, lose their mobility, and form a thick protective coat, known as the cyst wall. This stage is called the cystic or encysted stage. The newly-formed cyst is uninucleate (with one nucleus) but eventually develops into a four-nucleated cyst (Figure 6). Both the trophozoites and the cysts are excreted with the faeces of the victim. The trophozoites are very sensitive to temperature change, and soon die outside the human body. The trophozoites are thus not important in the transmission of the disease, but the encysted forms, the cysts, are more resistant to temperature change, and can survive for a long period outside the human body. Cysts are excreted in large numbers with the faeces of the infected person, and they are responsible for maintaining the transmission of the disease.

FIGURE 6. Various magnified stages of *Entamoeba histolytica*



A : trophozoite

B : uninucleate immature cyst

C : mature cyst

Actual size : 8 to 60 micron (a micron : $\frac{1}{10,000}$ of a centimetre)

Adapted from *Amebiasis Laboratory Diagnosis*, Part 1, II, US. Department of Health, Education and Welfare, Public Health Service Publication No. 1187 (1964). USGPO, Washington, D.C.

It is important to note that persons who pass cysts in their faeces may not reveal any sign of the disease. These persons are usually called "chronic cyst-passers", and are potentially dangerous transmitters of the disease, particularly when they are food-handlers. Man gets infected by ingesting these cysts with food or drink contaminated by the faeces of infected individuals.

Control measures against amoebiasis

1. The most effective control measure against amoebiasis is the proper disposal of human excreta.

2. The discharge of faecal material or untreated sewage into water sources - streams, rivers, unprotected wells and springs - must be avoided. It is worth remembering that the cysts remain viable for a long period both in sewage and in natural surface waters. It should also be noted that the dosage of chlorine customarily applied in water treatment will not destroy the cyst of *Entamoeba histolytica.*
3. Flies and other insects which are likely to have access to human faeces and then to foodstuff should be controlled.
4. Health education should be given to the public about the danger of improper excreta disposal; and about how amoebiasis is spread.
5. Food-handlers must be educated and supervised, particularly those who are likely to be chronic cyst-passers.
6. The use of untreated human faeces or sewage as a fertilizer for growing vegetables and roots which are customarily eaten raw or unpeeled should be discouraged.

2.6 CHOLERA

So far we have dealt briefly with excreta-borne diseases whose causative agents are mainly helminths, with one example of a disease caused by protozoa - amoebiasis. Here we take up one example of bacterial disease, cholera, which is transmitted through human excreta.

Cholera is one of the major most frightening and horrible epidemic diseases of the world. It is also known to be one of the greatest killers of man.

The causative agent is a microscopic, comma-shaped bacterium called *Vibrio cholerae*, or the comma bacillus. The organism lives and multiplies in the intestinal tract of man. The disease is characterized by sudden onset, vomiting, intense and persistent diarrhoea, quick dehydration (loss of body fluids), severe muscle cramps and gradual failure of the blood circulatory system. Generally a high proportion of untreated patients die within a short period after the onset of the disease.

The seriousness of the disease is mainly due to the loss of body fluids and the essential salts such as sodium and potassium salts which are present in the body fluids. The loss is caused by the intense watery diarrhoea and vomiting that characterize the disease. Because of this, the most important feature of the treatment of a cholera patient is usually the replacement of the lost fluids and salts which are nowadays given by mouth (oral rehydration).

The organisms are discharged with the watery diarrhoea, usually called rice-water stools because of its appearance, and the vomitus of the patient.

A healthy man gets infected by cholera by ingesting the bacteria with food or drink which have been contaminated by the watery diarrhoea (faeces) or vomitus of the patient.

Although *Vibrio cholerae* has very little resistance to disinfectants or to drying, it is believed to remain viable in stools for from one to several days. It is also believed to survive for from one to two weeks, or longer, in natural river water.

Control measures

NOTE. Cholera is one of the major internationally *reportable diseases.* Therefore, any suspected case of cholera should be reported by the fastest possible means to the nearest health department, the national capital city or the nearest World Health Organization (WHO) office of the region.

1. Because the transmission of cholera is through the watery diarrhoea and vomitus, the sanitary disposal of human excreta is the most effective method of cholera control.
2. The water supply available must be protected and treated. Boiling of water (if the treatment method is unreliable) before drinking should be enforced.

3. Strict sanitary inspection of food is required during preparation, storage and serving.
4. Fly control must be carried out with the elimination of breeding-places, prevention of flies from reaching foodstuffs, etc.
5. The public must be educated as to how the disease is spread, and what control measures are to be undertaken, both by individuals and by the community at large.
6. Vaccination against cholera is generally available. However, its protective value is not fully reliable as a control measure. Further, the vaccine is relatively expensive, and the immunity it gives does not last long. Consequently, vaccination is not usually recommended as a means of control, except in special circumstances.

CHAPTER THREE

THE IMPORTANCE OF EXCRETA-BORNE DISEASE TO PUBLIC HEALTH IN ETHIOPIA

The availability of safe water in a community, or of a waste disposal system, can influence its health more dramatically than the presence of several experienced physicians, who could only treat the effect without getting to the cause.

"World health priorities", in *The Magazine of the World Health Organization*, July 1976, p.3.

3.1 THE MAGNITUDE OF THE PROBLEM: SOME STATISTICAL EVIDENCE

Reliable statistical information on excreta-borne diseases is not available for the whole of Ethiopia. However, various studies made in different parts of the country indicate that human excreta-borne diseases are the most important health problem in the country. Quotations and summarized extracts from some of these studies, carried out by agencies or individuals in many different areas of Ethiopia, are given here, with comments, and with the sources shown above each entry.

1. *Annual Report on Weekly Notifiable Diseases, Ethiopia*, 1971 G.C. (Ministry of Health, Epidemiology Division, Addis Ababa) states with regard to intestinal infectious diseases: "In the year 1971, 39,895 dysentery cases were reported for the whole empire, and this figure accounts for 42% of all reported cases from the notifiable diseases. Among this group, 20,924 cases were amoebiasis and 17,444 cases bacillary dysentery, being at the same time the second and third most often reported diseases in Ethiopia. Shoa and Wellega reported the highest number of cases, Gamo Gofa and Ilubabor the lowest."
2. The same source gives the following information for 1972 G.C. (pp. 21 and 22): "Among 26 selected notifiable communicable diseases reported in 1972 by 237 health institutions throughout the country, 45.2% of all the reported diseases were under the category of 'Intestinal Infections'. Under this category of diseases, 68,408 cases of amoebiasis, bacillary dysentery, typhoid and paratyphoid fevers, infectious hepatitis and bilharziasis were reported for the whole country. This figure accounts for 45.2% of all the reportable diseases. . . . Amoebiasis and bacillary dysentery: both diseases combined accounted for 92.4% of the reported cases of intestinal infections. Among this group, 40,782 cases were of amoebiasis and 22,447 cases were of bacillary dysentery, being at the same time second and third leading causes of morbidity among all the reportable communicable diseases."
3. *The Annual Report on Weekly Notifiable Diseases, Ethiopia*, 1973 G.C., reported no change in the patterns of intestinal infections: amoebiasis (64,299 cases) and bacillary dysentery (25,718 cases) were still respectively the second and third diagnosis made among all the notifiable diseases.

NOTE: Ascariasis and similar parasitic diseases are not classified as "Reportable communicable diseases".

4. *Summary Report on Out-Patient Visits, Ethiopia,* 1962 *and* 1963 *E.C.* (*September* 1969 - *August* 1971 *G.C.*) (Ministry of Health, Statistical Division, Addis Ababa) (pp. 3-6, 8-9).

"The number of patients who were treated in hospitals, health centres and clinics, and for whom diagnosis, age and sex were indicated, in the country in 1962 and 1963 E.C. totalled 892,669 and 1,076,129 respectively. . . . Both in 1962 and in 1963 E.C., the five leading causes for treatment services were the same, and in the same order. They accounted for 30.3% in 1962 and 29.7% in 1963 E.C. of the out-patients treated in the hospitals and health centres. The five leading causes for out-patient treatment services were

1. Helminthiasis
2. Infections of the skin and subcutaneous tissues
3. Gastroenteritis and colitis
4. Dysentery, all forms
5. Venereal diseases."

Under the heading "Cases of out-patient services by diagnosis", the *Report* states: "On the average, both in 1962 and 1963 E.C., one patient of every three patients was seeking medical care for infective and parasitic diseases. The infective and parasitic diseases ranked first among the fifteen diagnostic groups as a cause for out-patient services. The annual rates for infective and parasitic diseases in 1962 and 1963 E.C. were 11.8 and 13.2 per 100 population respectively. In 1962 E.C., four of the ten leading causes for out-patient services were from the infective and parasitic diseases group. The four diseases (helminthiasis, dysentery, venereal diseases and malaria) accounted for 22.9% of the patients treated during the year."

The *Report* further indicated: "Selected on the basis of their frequency, the five leading diagnostic groups mentioned above were the five top-ranking causes among the male and the female patients separately, both in 1962 and 1963. . . . The infective and parastic group of diseases was first among the five leading diagnostic groups among the male and female patients separately and among all age groups (1-65 years and older)."

5. In an unpublished morbidity report of Ministry of Health of 1973 E.C. (1980/81), the order of the above five leading diagnoses in hospitals and health centres was as follows:

1.	Helminthiasis	214,005
2.	Dysentery, all forms	142,056
3.	Infection of the skin and subcutaneous tissues	114,069
4.	Gastroenteritis and colitis	113,760
5.	Venereal diseases	73,037

NOTE. Nos 1 and 2 alone make up 54% of the whole.

Thus, even in recent years (1973 E.C., 1980/81 G.C.), the health situation is similar to that of 1962 and 1963 E.C. (1969-71 G.C.). However, it should be noted that the increase in absolute numbers is mainly due to more complete reports, not necessarily to an actual increase of cases.

6. Blahos, J., and Kubastova, B. 1963. The survey of 11,170 patients treated in the Ras Makonnen Hospital in Harar [eastern Ethiopia]. *Ethiopian Medical Journal* 1, pp. 190-196.

"The greatest percentage of patients came to us with gastrointestinal diseases. . . . From the total number of 11,170 patients there were 4,072 patients with such troubles, i.e. 36.4%. An outstanding number represent diseases caused by parasites (44.9%); other diarrhoeas (18.5%), with or without proved causative factors, then gastritis. . . .

Out of a total 5,431 stool samples, 61.1% proved positive for parasites. In about 1/3, more than one parasite was found."

7. Lemma, A., Demisse, M., and Mezengia, B. 1968. Parasitological survey of Addis Ababa and Debre Zeit schoolchildren, with special emphasis on bilharziasis. *Ethiop. Med. J.* 6, 61-71.
   In Addis Ababa, "the total number of children whose stools were examined was 468, and of these, 73% were found to harbour one or more parasites. Fifty-three per cent of the examined children showed *Ascaris*, 15% *Trichuris*, and about 9% *Giardia*." In Debre Zeit, 47 kilometres south-east of Addis Ababa, "out of the total number of 90 children whose stools and urine were examined, 50% were found to harbour one or more parasites. It was interesting to note that, as in Addis Ababa, *Ascaris* was the most common parasite in Debre Zeit".
8. Freij, L. 1973. Observations on parasitic and bacterial infections of the intestine among paediatric out-patients in Addis Ababa. *Ethiop. Med. J.* 11, 13-24.
   "Three hundred paediatric out-patients from Addis Ababa were examined for intestinal protozoa and helminths. . . . *Giardia* was the sole parasite seen in infants under one year of age. Then the incidence of parasites increased rapidly with age. Children above the age of 6 years harboured *Entamoeba histolytica* in 11%, *Giardia* in 17%, *Ascaris* in 39% and *Trichuris* in 33%. Nonpathogenic protozoa showed the same age distribution. *Entamoeba coli* was the most common and occurred in 40% of the children above the age of 6 years."
9. An analysis of Mother and Child Health activity in the five training Health Centres (Public Health College, Gondar, north-west Ethiopia), between July 1969 and April 1970 G.C. was in part presented at the Annual Public Health Conference at the College on 19 June 1970. This showed helminthiasis as the first cause of morbidity in four of the Health Centres, and the second cause in the fifth, among the top ten diseases listed. Gastroenteritis averaged second in all five Health Centres.
10. Negusse, W-M. 1973. School health service in Ethiopia. *Ethiop. Med. J.* 11, 113-120.
    Of 20,992 diagnoses made by physicians at the Schools Health Centre, Addis Ababa, in 1971, 42.0% were diseases of the gastrointestinal tract and intestinal parasites. These diseases ranked first of the seven diseases listed.
11. Hojer, B., and Nordberg, E. 1973. Health survey of a rural elementary school in Ethiopia. *Ethiop. Med. J.* 11, 75-92.
    In a rural town in Wellega, in the highlands 320 kms west of Addis Ababa, 88% of 106 stools from 106 elementary schoolchildren were found positive for intestinal parasites. *Ascaris* headed the list of six parasites, with hookworm second.
12. Ey, J. 1974. School health survey in Ethiopia: a questionnaire study. *Ethiop. Med. J.* 12, 33-38.
    Covering a total of 43,153 students in 39 secondary schools in the 13 rural provinces of Ethiopia, a questionnaire health study showed that intestinal parasites (amoeba, *Ascaris*, hookworm, tapeworm) constituted 74% of illnesses and were first among the ten most commonly reported diseases.
    This particular study revealed that 28% of the schools had water on the school grounds. "So far as waste disposal facilities are concerned, 97% of the sampled schools had latrines on the school ground. However, in only 55% of these schools were the latrines regularly used. Several reasons were given for this non-use: nine of the schools (23%) had flush toilets with no running water and were locked; many were not maintained, and others were functional but students did not use them. . . . This study suggests that the schools are failing to interrupt the faecal host transmission of [intestinal] parasites on the school grounds, as well as failing to educate the students in the necessary practices for home."

13. Tsega, E., and Nadew, D. 1972. The threat of amoeba cyst carriers among hospital food-handlers. *Ethiop. Med. J.* 10, 47-52.
"Out of the total number of 61 kitchen workers and food-handlers [at the former Haile Sellassie I Hospital, Addis Ababa], 50 (82%) are carriers of cysts of *Entamoeba histolytica*. Some of them are victims of mixed infestation."
Commenting on this article in the same issue of the *Ethiopian Medical Journal*, the Editorial stated: "The figure of 82% infection rate in foodhandlers at the Haile Sellasie I Hospital is the second highest rate on record in the world, and is surprising in an urban population with adequate washing facilities and safe faeces disposal to hand."

14. Hagen, K., with Haakenso, R.C., Meless Gebrie and Abrehet A. Michael. 1974. "Epidemiological and clinical aspects of intestinal parasitism seen in Mekane Yesus Hospital, Woldia, Wollo [north-east Ethiopia]": an unpublished paper presented at the XIth Annual Medical Conference of the Ethiopian Medical Association, 30 May to 1 June 1975.
With reference to stool examinations made on 852 patients admitted to the provincial hospital in 1974, the comment is made: "The most significant finding of the whole study is that, while 64% of all patients tested showed one or more parasites in their stools, only 12% of these actually came to the hospital for gastrointestinal complaints."

15. Ayalew Admassu, Bekele Degefu, Moges Tiruneh, Sefefe Belai and Surfa Gobena. 1974. "Estimation of the prevalence of intestinal parasitism in Addis Alem village [10 km south-west of Gondar town], 1973-74": an unpublished paper presented at the 8th Annual Public Health Conference of the Public Health College, Gondar, 1974.
In a sample of 220 people (out of total population of 880) examined for ova and parasites in Addis Alem village, the infection rate was 95%. The infection rate was practically equal among the sexes (males 95%, females 94.8%).

16. The prevalence of parasitic infections recorded among new admissions (freshman classes) of the Public Health College, Gondar, for four consecutive years (Data compiled by the author).

(a) 1970/71 G.C. entrants (90 students of both sexes): 52.2% harboured one or more parasites;
(b) 1971/72 entrants (111 students of both sexes): 55.0% had one or more parasites;
(c) 1972/73 entrants (107 of both sexes): 53.3% were found positive for one or more parasites; and
(d) 1973/74 entrants (96 students of both sexes): 49.0% of them revealed the presence of one or more parasites.

The average infection rate for the four years was 52.4% (Table 1). The prevalence of individual parasites in the freshman class of 1970/71, and the infection rates for single, double and triple parasites are shown in Table 2.

The prevalence of *Ascaris* alone or with other parasites was 54.1% in 1971/72, 66.7% in 1972/73 and 75.5% in the freshman classes of 1973/74.

Student admission represented all the 14 Administrative Regions of Ethiopia; approximately one-third of the students were females for each admission year (Table 3).

TABLE 1. The prevalence of parasitic infections recorded among the freshman classes of the Public Health College, Gondar 1970/71 - 1973/74 G.C.

Year	Total No. of students submitting stools	Male	Female	Total positive for one or more parasites (both sexes)		Total negative (both sexes)		Multiple infections, two or more	
				No.	%	No.	%	No.	%
1970/71	90	53	37	47	52.2	43	47.8	18	38.3
1971/72	111	68	43	61	55.0	50	45.0	16	26.2
1972/73	107	62	45	57	53.3	50	46.7	16	28.0
1973/74	96	60	36	47	49.0	49	51.0	16	34.0
Total	404	243	161	212	52.5	192			

Average infection rate : 52.5%

NOTE 1. Stool examination for intestinal parasites is part of the medical examination requirements for all freshman classes.
2. The stool examination method used is the single direct-smear technique.
3. Age requirements for admission are normally 16 to 25 years.

TABLE 2. The prevalence of individual intestinal parasites in the freshman class of 1970/71 G.C. at the Public Health College, Gondar

SINGLE INFECTIONS

Parasites	No.
Ancylostoma duodenale eggs	1
Ascaris lumbricoides eggs	11
Entamoeba histolytica cysts	3
Giardia lamblia cysts	1
Hymenolepis sp. eggs	3
Schistosoma mansoni eggs	1
Strongyloides stercoralis eggs	3
Trichuris trichiura eggs	6

DOUBLE INFECTIONS

Parasites	No.
Ascaris/Hookworm	1
Ascaris/Giardia	1
Ascaris/Strongyloides	1
Ascaris/Trichuris	3
Strongyloides/Trichuris	4
Entamoeba histolytica/Giardia	1
Entamoeba histolytica/Oxyuris	1
Entamoeba histolytica/Oxyuris	1
Entamoeba histolytica/Trichuris	1
Giardia/Trichuris	1
Hymenolepis/Strongyloides	1

TRIPLE INFECTIONS

Parasites	No.
Ascaris/Hookworm/Strongyloides	1
Ascaris/Schistosoma/S. mansoni/Strongyloides	1
E. histolytica/S. mansoni/Strongyloides	1

PRINCIPAL PARASITES FOUND

Parasite	Single Infection	Multiple (with others)	Percentage positive of all stools examined
Ascaris	11	8	40.0
Trichuris	6	9	32.0
E. histolytica	3	4	15.0

TABLE 3. Public Health College, Gondar: Distribution of freshmen, 1970/71 - 1973/74, by Administrative Region (place of recruitment)

PROVINCE	1970/71	1971/72	1972/73	1973/74
1. Arssi	6	2	0	6
2. Bale	0	1	1	0
3. Begemdir and Semien (now Gondar)	21	22	24	14
4. Eritrea	12	9	12	4
5. Gamo Gofa	2	2	3	4
6. Gojam	6	7	8	6
7. Ilubabor	0	8	5	6
8. Harerge	6	13	10	11
9. Kefa	0	1	6	5
10. Shoa	14	24	18	13
11. Sidamo	3	7	4	5
12. Tigray	4	5	3	11
13. Wellega	13	7	9	7
14. Wello	3	3	1	4
Total	90	111	104+1 from Nigeria	96

17. *The Annual Report on Major Communicable Diseases and Vaccination Activities in Ethiopia*, 1966-1967-1968 *E.C.* (1973/74 to 1975/76 G.C.), (Ministry of Health, Division of Epidemiology) gives the following Table:

TABLE 4. Eight leading major communicable diseases 1973/74 - 1975/76

RANK	DISEASE	1973/74 No.	1973/74 %	1974/75 No.	1974/75 %	1975/76 No.	1975/76 %
1	Venereal diseases	290,750	45.6	201,907	30.2	205,119	32.2
2	Helminthiasis	121,250	19.0	159,718	23.9	126,216	19.8
3	Bacillary and Amoebic Dysentery	69,369	10.9	81,761	12.2	61,478	9.6
4	Gastroenteritis	66,614	10.6	79,560	11.9	81,138	12.7
5	Leprosy	N	—	59,090	8.8	61,939	9.7
6	Malaria	44,128	6.9	37,874	5.7	46,211	7.2
7	Tuberculosis	29,669	4.7	30,454	4.6	33,954	5.3
8	Bilharzia	15,919	2.5	19,413	2.9	21,801	3.4
	Total	637,699	100.0	669,777	100.0	637,856	100.0

1. "N" indicates no report available.
2. Percentages are given to one decimal.

AUTHOR'S NOTE. In this Table, Nos 2, 3, 4 and 8 are excreta-borne diseases, composing 42.8%, 50.8% and 45.6% of the total diseases reported respectively in 1973/74, 1974/75 and 1975/76. Using this criterion, venereal diseases do not rank first among communicable diseases.

18. In 1981 G.C., an unpublished report from the Ministry of Health, giving data taken only from the reporting hospitals and health centres, showed the rank order of communicable diseases as follows:

TABLE 5. Ministry of Health data: Communicable diseases, 1981 G.C.

RANK	COMMUNICABLE DISEASES	CASES	%
1	Helminthiasis	214,005	30.6
2	Dysentery, all forms	142,056	20.3
3	Gastroenteritis and colitis	113,268	16.3
4	Malaria	109,681	15.7
5	Venereal diseases	73,037*	10.4
6	Tuberculosis, all forms	39,555*	5.6
7	Leprosy	4,167*	0.6
8	Bilharzia	3,511*	0.5
	Total	699,780	100.0

*Not including reports from special projects, e.g. the Tuberculosis Centre, Venereal Disease Clinics, Leprosy Control, etc.

3.2 THE ECONOMIC IMPACT OF EXCRETA-BORNE DISEASES

The seriousness of illness (pathogenicity) caused by the several excreta-borne diseases which are described above will not be dealt with here, because that aspect is better handled by medical doctors. However, the damage the diseases cause to human welfare will be illustrated by taking *ascariasis* as an example.

Ascariasis is not generally believed to be a dangerous disease by non-medicals and other laymen. Nevertheless ascariasis does cause appreciable harm to man.

World Health Organization, "The Control of Ascariasis" (WHO Technical Report Series No. 379, 1967), states: "The various aspects of the harm inflicted by ascariasis on the community include the direct effects of the worm - causing overt morbidity and mortality - and the indirect effects - the promoting of other diseases by introducing the causative agents, or predisposing to other diseases, by introducing or aggravating malnutrition which may in turn retard the growth and intellectual development of children. The economic aspects of ascariasis, such as loss of working-time, loss of skill (through effects on school attendance and learning) and cost of treatment also need to be taken into account."

From the various studies (quoted in this book and elsewhere) carried out on adults, school and pre-school-age children, the average infection rate of ascariasis, alone or together with other parasites, is well above 50% (in many instances above 60%).

According to the Statistical Abstract for 1978 of the Central Statistical Office, the total population of the country was then 29,408,200. Of this population, the age-group 0-14 years (the group most affected by ascariasis) constituted 43.1% of the whole. Assuming that 50% of this age-group is infected at any time, it can be said that about 25% of the total population is infected: around 7,352,050 individuals.

Considering only one aspect of ascariasis control - treatment - then the economic impact of treatment alone will be as follows:

The number of people to be treated is about 7,352,050. The medicine called piperazine is generally the drug of choice for treating ascariasis. The current market price of piperazine (in Addis Ababa) for a single dose is about 2 Ethiopian Birr. Therefore, if the above population takes a single dose of piperazine once a year, the cost in terms of Eth. Birr (1 Birr = about US $ 0.50) will be 2×7,352,050, which comes to 14,704,100 Birr.

It is generally believed that a single dose of piperazine will not confer a complete cure; so a second dose, at least once in three months, is essential. Moreover, even if we assume that a single dose of piperazine will expel all the worms, the chances of acquiring reinfection are ever-present, because of the poor sanitary conditions prevailing. Hence, two doses of piperazine per person per year would be a minimum prescription for ascariasis treatment. Thus the estimated cost now is

$$7,352,050 \times 2 \times 2 = 29,408,200 \text{ Birr.}$$

Let us take another common disease which is indirectly excreta-borne in Ethiopia, or *kosso beshita*, as both the disease and the beef tapeworm are known.

Reliable records on the rate of tapeworm infection (taeniasis) are not available for the whole country, mainly because a large majority of the population do not go to medical centres but make their own diagnosis and take *kosso* (the traditional taenicide) every two to three months.

Nevertheless, the available statistics from health institutions reporting in the country indicate 32,680 and 32,443 cases of beef tapeworm infection for 1975 and 1976 G.C. respectively, giving an average of 3% of the total reported morbidity rate. In a more complete report (unpublished) of 1981 G.C., there were 44,672 cases, which accounted for about 3% of the total sickness rate.

It is also difficult to obtain a reliable prevalence rate of cysticercus bovis (the cyst stage in beef) among animals slaughtered for food. However, the veterinary doctor of Addis Ababa slaughterhouse estimates that from about 15% to 20% of the animals slaughtered in the city abbatoir are found to have cysts (Personal communication: Dr. Geremew Debele, June 1975).

Thus, because of lack of reliable statistics, it is difficult to determine the exact economic impact of taeniasis. However, considering only one aspect of treatment (money spent on imported or local drugs), a liberal estimate may be made on the basis of practical experience.

The current price of a single dose of taenicide varies from 65 cents Ethiopian for a locally made (Epharm) brand to 2.45 Birr for an imported brand in Addis Ababa. The minimum estimated cost of a single dose of home-made *kosso* is 30 cents (about 0.15 dollars U.S.) in Addis Ababa, and no less elsewhere.

Assuming that 3% of the total population of 29,408,200 (1978 estimate) took the home-made *kosso* preparation four times per year, at a cost of 30 cents per dose, then this amounts to

$$29,408,200 \times 3/100 \times 30/100 \times 4 \text{ Birr per year} = 1,058,695.20 \text{ Birr per year.}$$

While a large majority of people take various brands of "home-prepared *kosso*", relatively few take imported taenicides, such as niclosamide (tradename Yomesan) or dichlorophen. Here again it is difficult to reckon the financial implication. However, in the Amharic newspaper *Addis Zemen* for 19 Megabit 1968 E.C. (March 1976). Kessete-Birhan Wolde-Tsion calculated: "The minimum expenditure for the country on various brands of taenicides is about 3,415,386 Birr per year." He also noted that, according to the records from the few city slaughter-houses where meat is inspected by government inspectors, meat to the value of almost one million Birr was condemned as unsuitable for human food in 1967 E.C. (1974/75) because of cysticercus bovis.

Unpublished data compiled by the Pharmacy Division of the Ministry of Health reveal that antihelminthiasis against various types of worm infestation in the years 1980 and 1981 G.C. cost Ethiopia about 6.6 million and 5.6. million Birr respectively. The data also show that, out of the total cost in 1980 and 1981 G.C., the major part, Birr 5.2 million (79%) and Birr 4.2 million (76%) respectively, was spent on anti-tapeworm drugs.

In addition to the cost and the loss of working days, we should take into account the adverse side-effects of taenicidal drugs, particularly home-prepared *kosso*. In *Collected Research of the Soviet Red Cross Hospital in Addis Ababa*, 2nd issue, p. 15 (1962 G.C.), we find: "According to the figures of the Therapeutic Department as well as laboratory investigations of the Soviet Red Cross Hospital, parasitic worm infections are very common amongst the Ethiopian population. They constitute 76.8% of all helmintho-coprologic test results (worm in excrement test results), and it is quite common to encounter cases of simultaneous infection by two, three, or more kinds of helminth. When local people wish to rid themselves of these worms, they often use an age-old form of treatment, i.e. they take *kosso* (*Hagenia abyssinica*). Since this is usually taken other than by doctor's prescription, it sometimes results in severe poisoning, with burns of the mucous lining of the stomach and intestinal bleeding. It is interesting to observe that the incidence of *kosso* poisoning in fact increased from 4.5% in 1959 to 12% in 1961."

The financial and economic impact expressed in this section may not be accurate to the last Birr or cent; yet we can clearly realize that excreta-borne diseases provide an extremely important public health problem in Ethiopia.

3.3 THE IMPACT OF INSANITARY ENVIRONMENT ON INFANT MORTALITY

The infant mortality rate is defined as the number of babies who die before reaching their first birthday per 1000 babies born alive in a specific year. The risk of death is higher for a newborn baby during the first year of life than at any other time in its lifetime. This is because the newborn infant is most vulnerable to the home conditions in which it is born. If the living conditions in that home are poor, particularly from the sanitary aspect, then there is a much greater risk that the infant may fall ill and die.

Consequently, the infant mortality rate is one of the sensitive yardsticks used worldwide for measuring the level of health achievement in a nation or a community.

The estimated infant mortality rate is about 155/1000 in Ethiopia, while in most developed countries this rate ranges from less than 20/1000 to 30/1000 live births.

Expressed in another way, in Ethiopia, every year, about one-fifth of the babies born alive die before reaching their first birthday.

Although the high infant mortality rate is attributed to several factors, such as inadequate knowledge of infant feeding, respiratory diseases, etc., the infant diarrhoea and enteritis, which is caused by lack of basic sanitation and hygiene, plays as large a role as, and perhaps a larger role than any other childhood disease.

It is difficult to substantiate this statement with accurate data, mainly because of lack of community-based studies on the subject. However, in *Acute Enteric Infections in Children* (editors T. Halm, J. Holmgren, M.H. Merson and R. Mollhy; Biomedical Press, Elsevier, Holland), published in 1981, a well-informed article (Chapter 6) appeared, entitled "Epidemiology of acute diarrhoeal diseases in children in Addis Ababa", written by Demissie Habte, G. Stintzing and A. Thoren. This stated: "Acute diarrhoeal disease is an important cause of morbidity and mortality in children throughout the world, but is particularly common in developing countries. . . . Acute diarrhoeal disease is the commonest cause, after respiratory disorders, of visits to clinics and out-patient departments in the paediatric age group." L. Freij and S. Wall (Exploring child health and its ecology. *Acta Paediatr. Scand., Supplement* 267, 1-152, 1977), in a one-year prospective community study in Addis Ababa, concluded that children under 2 years were ill for 104 days of the year, and on 59 of those days the disease was diarrhoea.

In many developed countries, observations over the years have shown that, through the persistent practice of basic sanitation (proper excreta disposal, safe water supply, food and insect control), infant mortality rates dropped dramatically.

3.4 THE CONDITIONS OF HUMAN WASTES DISPOSAL IN ETHIOPIA

No person shall urinate or defaecate in any place except in a properly constructed latrine. Any person found urinating and defaecating in a place not intended for this purpose will be liable to a fine of Eth. Birr 0.25 (*twenty-five cents*) *or imprisonment of twelve hours if he is not able to pay.* Municipal Sanitation Rules of 1951 G.C., 10/12 (1951) L. 157.

The Public Health Proclamation cited above has been in existence for well over a quarter of a century. If it had been strictly enforced, we would assume that there would be adequate sanitary excreta disposal systems everywhere in the country, or the fine of 25 cents collected for each offence against the law could have generated a large amount of revenue for the government. In either case, the enforcement of this proclamation presupposes the existence of toilet facilities everywhere in townships. If this is not true, then this proclamation is unrealistic, and not enforceable.

Although it is difficult to obtain reliable data about excreta disposal in Ethiopia, certain records reveal a general picture of the problem.

1. The Central Statistical Office, "Survey of Major Towns in Ethiopia" (1968 G.C.), presents the following survey (analysed) of excreta disposal systems:

TABLE 6. Demographic and housing characteristics: Group A towns. Survey of major towns in Ethiopia (CSO, Addis Ababa, December 1968, Bulletin 1) Households by type of toilet facilities

No.	TOWN	POPU-LATION	FLUSH Number	%	PIT Number	%	NONE Number	%
1.	Adua	12,940	10	0.3	770	24.1	2,420	75.6
2	Akaki	10,924	60	1.8	770	22.8	2,550	75.4
3	Asbe Teferi	7,359	10	0.5	1,240	64.9	660	34.6
4	Assab	10,945	435	9.2	496	10.5	3,779	80.3
5	Assela	13,886	–	–	1,410	38.8	2,220	61.2
6	Axum	13,906	10	0.3	910	26.3	2,540	73.4
7	Bahar Dar	12,463	83	2.1	922	23.4	2,933	74.5
8	Debre Berhan	9,188	45	1.5	688	22.2	2,364	76.3
9	Debre Marqos	21,536	–	–	2,750	41.1	3,940	58.9
10	Debre Zeit	22,055	100	1.6	4,040	63.6	2,210	34.8
11	Dessie	40,619	110	1.0	4,980	47.3	5,430	51.7
12	Dilla	11,287	20	0.7	1,680	57.1	1,240	42.2
13	Dire Dawa	50,733	730	5.4	9,910	72.8	2,970	21.8
14	Ghion	8,627	20	0.9	1,100	50.2	1,070	48.9
15	Gondar	30,734	160	1.9	4,090	48.3	4,220	49.8
16	Hagere Hiwot	8,181	60	2.6	630	27.2	1,630	70.2
17	Harar	42,771	170	1.4	6,480	54.0	5,350	44.6
18	Jimma	30,580	210	2.7	3,880	49.2	3,800	48.1
19	Lekemt	12,691	–	–	1,380	44.5	1,720	55.5
20	Mekele	23,105	30	0.5	3,610	58.4	2,540	41.1
21	Shashemene	7,837	–	–	490	26.3	1,370	73.7
22	Sodo	10,842	10	0.4	620	21.9	2,200	77.7
23	Yirgalem	10,727	10	0.4	1,670	64.0	930	35.6

1. In this survey, the CSO defines "Group A" towns as the 23 relatively middle-sized towns listed above, and excludes Addis Ababa and Asmara.

2. The word "toilet" refers to a place for defaecation attached to the house or located within the compound where the household lives. A flush toilet has an attachment for running water. The word "pit" includes both open pit and covered pit.
3. Average household size: 3.3 persons.

It can be calculated from Table 6 that, on the average, only 1.5% of the 23 towns listed had water-carriage or flush toilets; 42.0% had pit latrines; 56.5% had no organized excreta disposal system whatsoever.

The same Survey, covering 169 smaller towns (excluding the Group A towns listed in Table 6, and of course Addis Ababa and Asmara) in 13 Administrative Regions, indicated that, on the average, 1.2% of these towns had flush toilets, 29.1% pit latrines, and 70.7% had no sewage disposal units at all (Table 7). Of the last, among the 13 Administrative Regions, the percentage of small towns which had no system of excreta disposal ranged from 52.7% to 85.2%.

TABLE 7. Demographic and housing characteristics, Group B towns. Summary by Provinces, Survey of major towns in Ethiopia (CSO, Addis Ababa, December 1968, Bulletin 1). Households by type of toilet facilities

No.		FLUSH TOILET		PIT LATRINE		NONE	
		Number	%	Number	%	Number	%
1	Arssi	–	–	1,380	25.0	4,140	75.0
2	Begemdir	60	0.5	2,400	20.7	9,110	78.7
3	Eritrea	2,315	11.8	3,890	19.9	13,340	68.3
4	Gamo Gofa	–	–	1,860	47.3	2,070	52.7
5	Gojam	–	–	1,490	24.0	4,720	76.0
6	Harerge	80	0.6	3,900	30.1	8,970	69.3
7	Ilubabor	50	0.9	2,410	41.8	3,310	57.3
8	Kefa	–	–	2,090	36.0	3,710	64.0
9	Shoa	100	0.4	6,680	23.5	21,600	76.1
10	Sidamo	110	0.9	5,110	43.7	6,480	55.4
11	Tigray	10	0.1	1,560	14.7	9,010	85.2
12	Wellega	10	0.1	3,250	29.0	7,940	70.9
13	Wello	30	0.2	2,860	21.2	10,620	78.6

Unfortunately the Survey does not indicate the sanitary conditions of the existing system: whether they are properly constructed and regularly used or not. Excreta-borne diseases might well exist even in those households which had been declared to have flushing systems or pits.

2. Another publication of the Central Statistics Office (CSO), *Urbanization in Ethiopia* (Bulletin 9, 1972 G.C.), with reference to the large cities respectively in the north, centre and east of Ethiopia, gives the following information:

In Asmara 15% of the households, in Addis Ababa 8% and in Dire Dawa 5% had flush toilets, whereas less than 3% of the households in the rest of the big towns had flush toilets. With the exception of those in Eritrea, towns with 5,000 to 20,000 inhabitants had in general no flush toilets at all.

Thirty-five per cent of inhabitants in big towns (49% when Addis Ababa is excluded), and 45% in smaller towns had no toilet facilities at all, which means that the problematic toilet situation is, on average, more severe in the bigger towns than in the smaller ones, when Addis Ababa is excluded from the former category.

Although reliable up-to-date data are lacking, it can be assumed that, after the Revolution in 1974 G.C., the number of sanitary facilities, particularly of non-water carriage systems, has increased. For instance, during the two-year period 1972 and 1973 E.C. (1979/80 and 1980/81), the following were reported to the Ministry of Health (unpublished report) by health institutions throughout the country, including those which were constructed by participants in the National Literacy Campaign:

1. Number of pit latrines constructed	121,488
2. Refuse disposal pits dug	63,844
3. Spring protected (mainly by fences and diversion ditches, rather than by cement walls)	36,349
4. Water wells protected	7,306

The important factor is not, however, the numerical increase of sanitary facilities, but whether these facilities have influenced the decrease of the incidence of excreta-borne diseases, which is difficult to prove.

3.5 HUMAN WASTES DISPOSAL SYSTEMS IN ADDIS ABABA

The public health problems of Addis Ababa, particularly the sanitary conditions, have been studied by various experts in the past. One of these studies was made in the rainy season of 1964 G.C. by E.C. Jensen and J.W. Tesch, W.H.O. short-term consultants, and presented as an assignment report: *Survey and Assessment of Municipal Health Problems of Addis Ababa*, EM/ES/78, Ethiopia 34/R, October, 1965. In this they described the situation (pp. 3, 16):

"Some very modern commercial buildings, offices, residences and streets distributed strategically over the entire city very definitely obscure a view of the true situation at first glance. One only needs to look behind one of these modern buildings to find sewage being discharged directly into a stream or into an overflowing septic tank."

Under the heading "Sewage and Drainage (Addis Ababa)", the report states:

"Of particular note at this point is the fact that there is no central sewer system for any part of the city. The wastes accumulate where they are deposited - next to the residences and places of business.

"The situation is deplorable, even when measured by standards in other developing countries. It is much worse than in rural areas and small communities, which have demanded concerted action all over the world for years. Where there is much open space, there is an opportunity for the removal of filth from where the people live. But in Addis Ababa, the size of the city and the density of development preclude any escapement or temporizing effect of nature, with the result that the hazardous waste accumulations literally surround the population.

"The latrine or privy methods of excreta disposal are usually regarded as satisfactory. But as these methods are constructed in Addis Ababa, the pits are usually shallow and open to flies and rodents. They overflow onto the surface of the ground, and the filth is spread to the surroundings where the people live and prepare their food, and where the children play. Under these conditions it is inevitable that there is much direct transmission of faeces to the mouth."

Relating the excreta disposal systems of Addis Ababa to health, the Report adds: "The dangerous excreta disposal practices appear to be the major causes of the high rate of intestinal diseases in Addis Ababa. . . . It has been established that infant mortality from diarrhoea and enteritis in Addis Ababa is from three to five times higher than that in the developed countries.

"Further, the records provide adequate evidence that, as sanitary waste disposal practices are introduced, there is a drastic reduction in intestinal disease rates."

In 1970 G.C., *Water Supply and Sewerage Feasibility Studies of Addis Ababa*, Volume 3, p. 6, October 1970 (Special Reports, Municipality of Addis Ababa, International Bank for Reconstruction and Development), contained the following information:

"A vast majority of the population use dry pit latrines. But, due to the concentration and consequent lack of space, the pit latrines are usually close to the places where food is stored and prepared. Most of them are accessible to flies and rodents. In rainy seasons they are often filled up with storm water, and the filth is spread over the ground. . . . Due to the lack of sufficient public and private sanitary facilities, there is also extensive promiscuous defaecation along the stream banks (and even in the stream beds in the dry season), in cemeteries and open areas. The modern villas and other recent buildings have water flush toilets and water-carried waste private systems. Most of these systems use septic tanks and cesspools."

For the same year, the Medical Officer of Health, Ingemar Gahnstedt, in his *Report from the Public Health Department, Municipality of Addis Ababa, February* 1970 - *May* 1971 *G.C.*, pointed out that there were then 14 public toilet facilities in Addis Ababa; at times, for various reasons, some of these facilities did not function properly.

Dr. K. Komolrit and Firdu Zawde (both Sanitary Engineers), who conducted an important scientific investigation on the sanitary condition of the streams flowing through Addis Ababa, reported results in *Studies and Assessment of Water Pollution in the Awash River and its Tributaries in the Upper Basin Region* (Public and Environmental Health Control, 1974 G.C. 3002/WHO/UNDP). Quotations from this work are given below:

"The results of laboratory analysis of eleven samples, taken at random from five streams in Addis Ababa, showed that four were highly polluted, four were polluted and the remaining three were slightly polluted. . . . Wastes from industrial, domestic and private sources were drained to these streams as they flow through the highly urbanized and industrialized part of Addis Ababa. Garbage, refuse and septic tank collections were prevailing along the banks of most of the streams within the Addis Ababa municipality boundary.

"The obnoxious smell along the banks of these streams was also a major public health nuisance, and the black appearance was derived from decomposition of sanitary wastes consisting of excrement, septic tank effluents, grease, oil, and industrial wastes which reached the water course. Many industrial establishments, public and apartment buildings, hotels and hospitals discharge their wastes into these streams through storm sewers, with the consequent use of the streams as places for refuse, garbage and waste disposal. Needless to say, the acute shortage of public toilets in the city has turned these streams into open-air sanitary conveniences. It is in this part of the city where the streams' sanitary condition is at stake, and, unless efforts are made to improve the prevailing conditions, the stream pollution remains to be a threat to the environment, and above all to the people downstream, whose livelihood still very much depends on these waters for all domestic purposes, cattle-drinking, fishing and irrigation."

During a conference held in Botswana in August 1980, Aragaw Truneh, General Manager of the Addis Ababa Water and Sewerage Authority, commented on the current sanitary situation in Addis Ababa (Proceedings of a Workshop on Training in Sanitation in Developing Countries, p. 52, IDRC-168e, International Development Research Centre, Canada). Modern villas and apartments, together with large institutions such as Addis Ababa University, hospital, hotels and industrial complexes, used cesspools and septic tanks. When these were full, the sewage was emptied into fleets of vacuum trucks (if the trucks could get access to the tanks) at a service charge of about Birr 30 per truck trip. The sewage, and also the solid wastes of the city, were then discharged on open fields at a public garbage dumping-site on the south-west outskirts of Addis Ababa, near the Jimma Road. On the other hand, some of the city's residential buildings and the majority of the industries discharged their wastes directly into the nearby streams, which were grossly polluted. Both practices create imminent public health hazards to the surrounding communities.

In *Statement on the Addis Ababa Sewerage Project*, an unpublished report by the Addis Ababa Water and Sewerage Authority, 17/6/68 E.C. (1976 G.C.), by Kelkilew Taddesse, then Acting General Manager, the estimated costs incurred for treating excreta-borne diseases in the city were over 4 million Birr and 6 million Birr for the years 1961 and 1967 E.C. (1968/69 and 1974/75 G.C.), respectively.

Very recently, in 1982 G.C., the Addis Ababa Water and Sewerage Authority produced their *City of Addis Ababa Sanitation Master Plan, Phase I.* In this, from data given by three major hospitals and 14 clinics in Addis Ababa, the following Table was drawn up:

TABLE 8. Reported cases of excreta-, water- and food-associated diseases in Addis Ababa 1970-1972 E.C. (1977-1980 G.C.)

	DIAGNOSIS	1977/78 G.C. Number	%	1978/79 G.C. Number	%	1979/80 G.C. Number	%
	All diagnoses	137,972	100.00	250,669	100.00	260,186	100.00
1	All types of dysentery	3,180	2.31	11,603	4.63	12,991	5.00
2	Infectious hepatitis	100	0.07	370	0.15	173	0.07
3	All types of schistosomiasis	99	0.07	157	0.06	14	0.01
4	Hookworm (more soil-related)	75	0.05	185	0.07	95	0.04
5	All types of helminthic infections	12,269	8.89	28,894	11.53	26,439	10.16
6	Gastroenteritis	16,055	11.64	33,580	13.40	28,469	10.94
	Total of 6 diseases	23,778	23.03	74,789	29.84	68,181	26.22

Obviously, present practices do not satisfy the criteria for proper excreta disposal. nor are they helpful to the improvement of standards of public health.

3.6 THE NEW SEWERAGE SYSTEM PLANS

The Addis Ababa Water and Sewerage Authority's thorough study of the city's human waste disposal problem resulted recently in a Report which we have already quoted: *City of Addis Ababa Sanitation Master Plan, Phase I.* In this, the *Preliminary Development Proposal* (January 1982 G.C.) puts forward the construction of a partial sewerage system for the city, to be carried out in two phases. In fact, the construction of the first phase, a sanitary sewage system and sewage treatment plant, started in 1977 G.C., and is nearing completion at present (1982 G.C.). Construction of the second phase is planned to start in December 1983.

Upon completion of the two phases, the ultimate target population to be served will be limited to those in the central commercial core of Addis Ababa, affecting possibly 150,000 to 200,000 citizens (one-sixth of the 1,300,000 city population estimated in 1981 G.C.), mainly in the south and south-western area, where there are many modern stone-built blocks of housing, serving as commercial public buildings, apartment housing, foreign embassies, etc.

The treatment plant, located at an area called Kaliti, on the south-western outskirts of Addis Ababa, is designed to receive sewage from the residential and public quarters, as well as contents from cesspools and septic tanks.

The treatment method devised is that of the Oxidation Pond or Waste-Stabilization System, described later in this book.

With regard to the cost and coverage of the proposed sewerage system, the Report (p. 14) states: "The Sanitary Sewerage System is prohibitively expensive for Third World urban areas. In Addis Ababa, specifically, the sewerage system . . . will cost U.S. $20 million."

The Report comments on the technical difficulties of constructing a working sewerage system to serve the entire needs of Addis Ababa, on unsuitable geological foundations and among densely-packed groups of mud (*chiqqa*) houses. In addition to the technical obstacles, the magnitude of the costs shows that sewerage for the entire city is not feasible. "The Sanitation Master Plan, of necessity, must consider other, more appropriate methods of providing urban sanitation facilities."

Of course we have to realize that the problem of human wastes disposal is not unique to this country, but is worldwide, particularly in the developing countries. But it is worth noting that the problem is one of the least understood *health* problems in Ethiopia.

Ethiopia cannot fully achieve a healthy economic level without improving the health conditions of her people. One of the practicable and economically feasible areas where such effective health improvement can be brought about is in the area of human wastes disposal. Through proper human excreta disposal, such debilitating common diseases as amoebiasis, hookworm, ascariasis, schistosomiasis, bacillary dysenteries, etc., could practicably be prevented, with consequent improvement in the health status and work-power of the people.

In the following chapters we shall look into some of the common, appropriate and practicable methods used for excreta disposal.

CHAPTER FOUR

SOME NON-WATER CARRIAGE METHODS OF HUMAN WASTES DISPOSAL

Among preventive measures, the most effective, the quickest, the cheapest is basic sanitation of the environment. By this we mean those simple, elemental things such as getting human excreta off the surface of the ground, giving the people clean water to drink and uninfected food to eat, and protecting them from the bites of disease-carrying insects.

Dr. Herman G. Baity, Director, Division of Environmental Sanitation, World Health Organization. 1954. *Bull. Wld Hlth Org.* 10, 139-314.

OBJECTIVES OF HUMAN WASTES DISPOSAL

As we have observed, excreta-borne diseases, with the exception of schistosomiasis, ancylostomiasis and tapeworm, may be contracted when we put into our mouth food, water or other beverages (milk, etc.) that have been contaminated with human wastes, whether faeces or sewage. For the transmission of schistosomiasis, ancylostomiasis and tapeworm, the role of human wastes is indirect, that is, we encounter these diseases by wading in water contaminated with faeces or urine, by walking barefoot on soil which has been infested with viable eggs of hookworm, or by eating raw beef that has been infected by the cysts of tapeworm. Therefore, the cardinal objective of human excreta disposal should be to isolate totally human excreta from man's food, water, and the immediate environment at large, that is

1. To prevent contamination of water sources (surface and ground)
2. To prevent contamination of surface-soil
3. To prevent accessibility of flies and other animals to human wastes
4. To avoid or minimize the direct handling of fresh excreta
5. To provide privacy and convenience while we are relieving ourselves
6. To eliminate bad odour, which attracts flies, and the unpleasing sight of areas defiled by human excreta.

It should be noted that any excreta disposal methods that we may use must satisfy the above objectives.

(A) Points to consider before selecting one particular system of excreta disposal

There are many different excreta disposal systems used in the world. The choice of a particular system will depend on several factors, of which the main ones are

1. The climate and the nature of soil formation of a given area
2. The type of construction materials required for a specific system, and their availability at reasonable cost in the community
3. The financial capacity of the community to support a specific system of excreta disposal
4. The prevailing habits and customs of the community with regard to excreta disposal; its awareness of the danger of human excreta as an imminent source of disease
5. The aptness of a particular system: to install, to use and to replace it when need arises.

Lastly, whatever method of excreta disposal is chosen, the individual, the family and the community at large must actively be involved in the choice, design, installation, and maintenance of it; everyone must be resolutely determined to use the system and to keep it working.

(B) Two common methods of human wastes disposal

Human wastes disposal methods can be broadly divided into two types:

1. The non-water carriage system
2. The water carriage system.

The *non-water carriage system* is a system which normally does not use water for carrying away or transporting human wastes. A typical example of this method is the pit latrine.

In a *water-carriage system*, the excreta are deposited directly into properly constructed *sanitary fittings*, and are then carried away by water through a closed piping system (drainage) to the final disposal site. We should notice that in this system, water is used primarily as a transporter of excreta, and becomes contaminated in this process. A typical example of this system is the septic tank method of excreta disposal.

This chapter deals with some non-water carriage systems of sewage disposal.

4.1 THE SHALLOW TRENCH OR SHALLOW HOLE LATRINE

The toilet area shall be outside the camp. Each man must have a spade as part of his equipment. After every bowel movement, he must dig a hole with the spade and cover the excrement.

The Bible, Deuteronomy 23: 12-13.

According to the Old Testament, the above rule was prescribed by Moses, between 1300 B.C. and 1200 B.C., to his people while he was leading them out of the land of slavery into the wilderness, where they wandered for forty years before reaching the promised land (Exodus 17:31-35).

This rule is one of the Mosaic Sanitary Laws that the followers of Moses strictly observed to ensure the proper disposal of human body wastes in their camps. If it is properly carried out in a suitable place, this method of human excreta disposal is as sound a rule of sanitation today as it was in about 1200 B.C.

This method is nowadays known as the *shallow trench method* (also sometimes called the "cat method"), since it makes use of a shallow trench or hole dug in the ground according to specific dimensions.

Each trench should be dug 25 to 30 centimetres wide, 60 cms deep, and as long as desired (depending on the number of users). It should be situated about 100 cms from the next trench, and it should allow 60 cms of length per person. Generally, one trench, about 3 metres long, can serve around 25 persons for 3 to 5 days.

The earth removed while digging is piled up at one or both ends of the trench. A shovel or scoop is placed in each pile of earth. Each person relieves himself, or herself, and immediately covers the excreta with the dug earth.

When the trench is almost full, it is carefully covered and new ones are dug as described above.

Privacy can be provided with a roof and screens of thatch or any other locally available material.

This type of latrine is very suitable for people who are on the move, such as soldiers, boy scouts or school clubs, campers, worshippers at festival sites, etc., as a temporary measure.

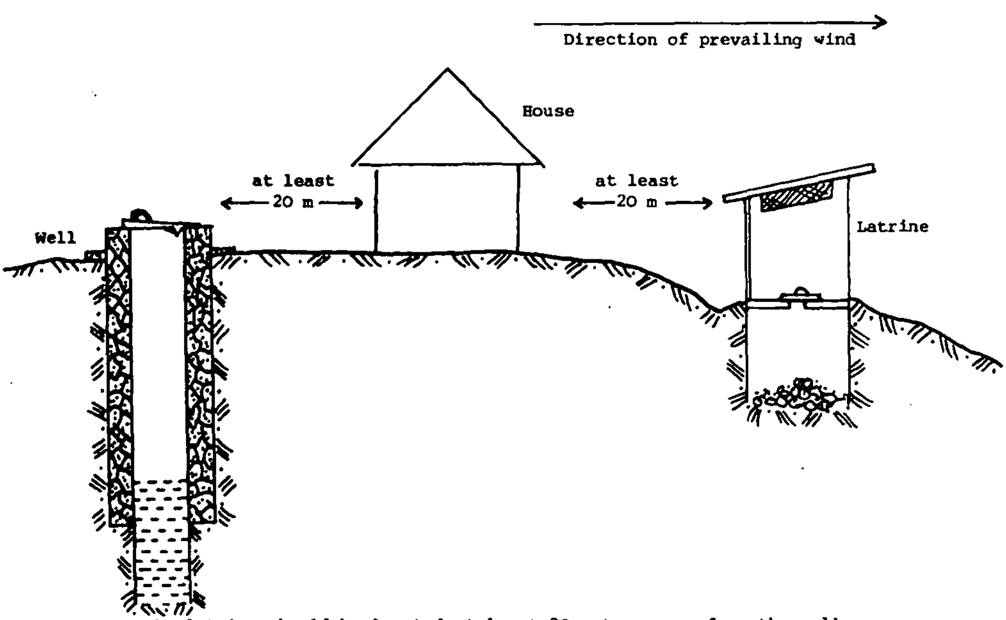
It is important to bear in mind that in this system the depth of the trench should not be deeper than 60 cms, as the decomposition of the excreta is brought about by the aerobic bacteria that thrive well in the top portion of the soil. It is also important to note that each person must cover the excreta promptly after defaecation, in order to prevent foul odours and the attraction of flies.

4.2 THE PIT LATRINE

The pit latrine is one of the commonly used systems of excreta disposal in many parts of the world, including developed countries in rural areas. It is simply a hole dug in the ground according to specified dimensions, and usually provided with means for squatting or sitting.

1. **Shape and dimensions.** These vary from place to place. Generally a hand-dug latrine is circular in shape, 80 to 120 centimetres in diameter, with the depth varying from a minimum of 2.5 metres to 5 m or more.
2. **Siting of the latrine.** The proper location of a pit latrine depends on several factors:
   (a) For greater convenience, it should be located near the home, usually from a minimum of 20 m to a maximum of 50 m. If it is too near the house, it will create a nuisance and bad odours. If it is too far from the home, the likelihood of using it regularly may be reduced.
   (b) From the sanitary point of view, which is the most important factor, the pit should be located below the level of any well or water source, at a minimum distance of 20 to 30 m, and on the up-wind or leeward side, so that the prevailing wind blows away from the pit, but not towards the home. If the pit latrine is located higher than the level of the well, or too close to the well, it will contaminate the well water through infiltration. A suitable location for a latrine is shown in Figure 7.

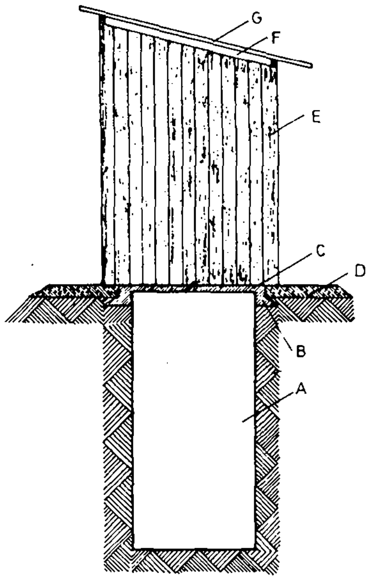
FIGURE 7. A suitable location for a latrine



The latrine should be located at least 30 metres away from the well or other water supply, so that infiltration of contaminated fluids is unlikely. The latrine should be sited on a level lower than that of the water supply, so that surface contamination cannot reach the water in times of rain.

3. **Digging of the latrine.** The pit latrine can be dug with any locally available equipment. As indicated above, the diameter of the pit should be not less than 80 cms and not more than 120 cms. If it is less than 80 cms, digging may be difficult; and if it is wider than 120 cms, it may be expensive to cover the hole. The depth of the pit should not be less than 2.5 m, in order to avoid fly-breeding. It is important that the pit should have a well-fitting cover with a handle, and this cover should be lifted only during the use of the latrine. With a minimum depth of 2.5 m, and a cover which is regularly used, fly-breeding is usually prevented.
4. **Completing the latrine.** After the digging of the pit is finished, the earth at the top of the pit should be packed hard and raised about 15 cms above the level of the surrounding ground. The raised area is then covered with a wooden, bamboo or concrete slab with a hole in it over the pit itself; the materials used will depend on local conditions. If a reinforced concrete slab is used, it is easy to keep clean; moreover, it is not affected by termites or by other organisms. Privacy may be provided by building a superstructure over the latrine. The superstructure may be built from simple, locally available materials, such as bamboo or wattle, or from corrugated iron sheets. A simple type of pit latrine, with its various parts, is shown in Figure 8. Another type of pit latrine, with a reinforced concrete slab, is shown in Figure 9. See also Figures 10 - 12. For technical details on pit latrine construction, some sources are listed under "Selected References", at the end of the book.

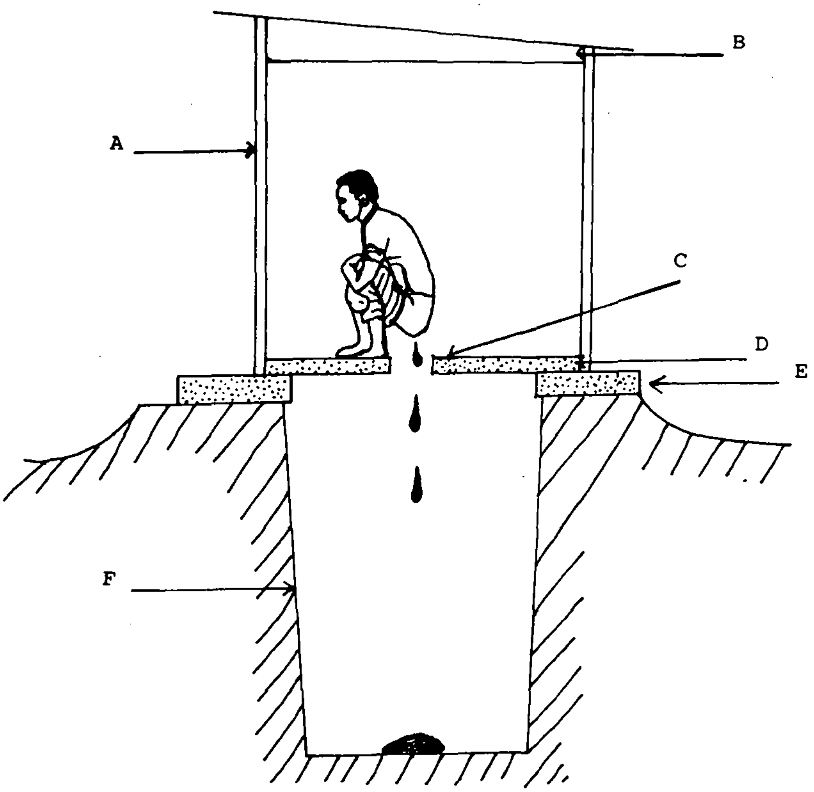
FIGURE 8. Various parts of a sanitary latrine



A : pit
B : base of the latrine
C : concrete floor (the hole for defaecation is not seen in this view)
D : mound of earth
E : latrine shelter (door not seen)
F : space for ventilation under roof (usually screened with wire net to discourage flies)
G : roof

Reproduced from W.H.O. Monograph No. 39 (1958)

FIGURE 9. A pit latrine



: shelter for latrine

: space for ventilation (screened)

: hole for defaecation into pit (16 centimetres diameter); cover with handle not shown

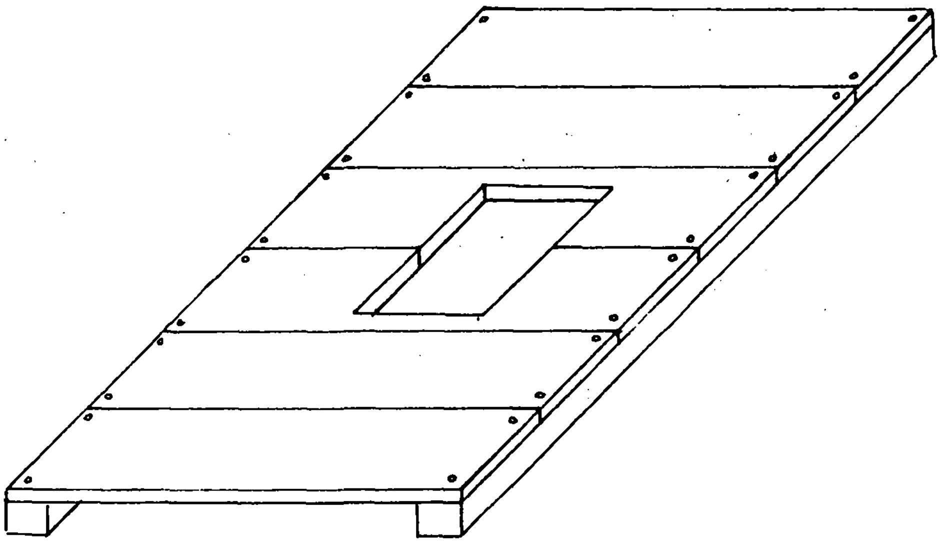
D : squatting plate

E : raised concrete slab above mound of earth

F : pit (not less than 1 metre diameter, and not less than 2.5 metres deep)

FIGURE 10. A squatting-plate or slab made of wooden planks

(Scale 1 : 100)



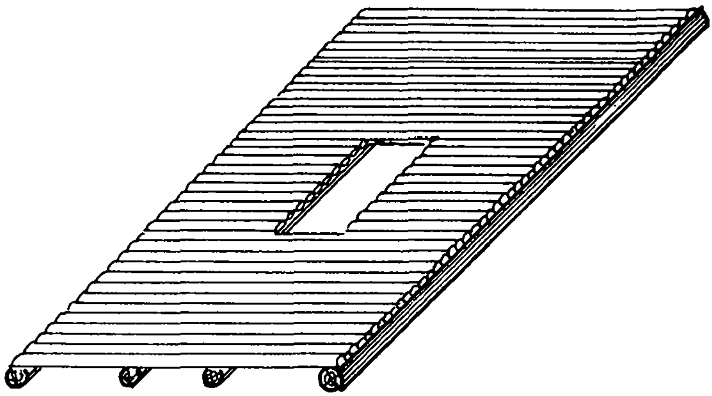
Reproduced from W.H.O. Monograph No. 39 (1958)

FIGURE 11

Squatting-slabs made from logs of wood

(Scale 1 : 100)

Adapted from W.H.O. Monograph No. 39 (1958)



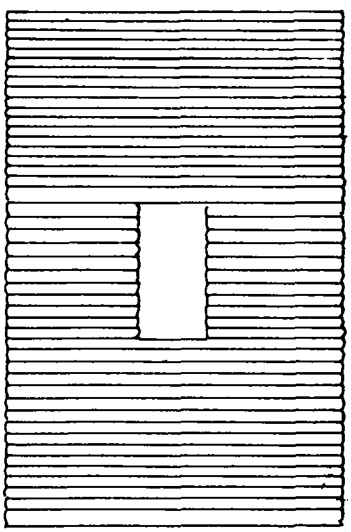
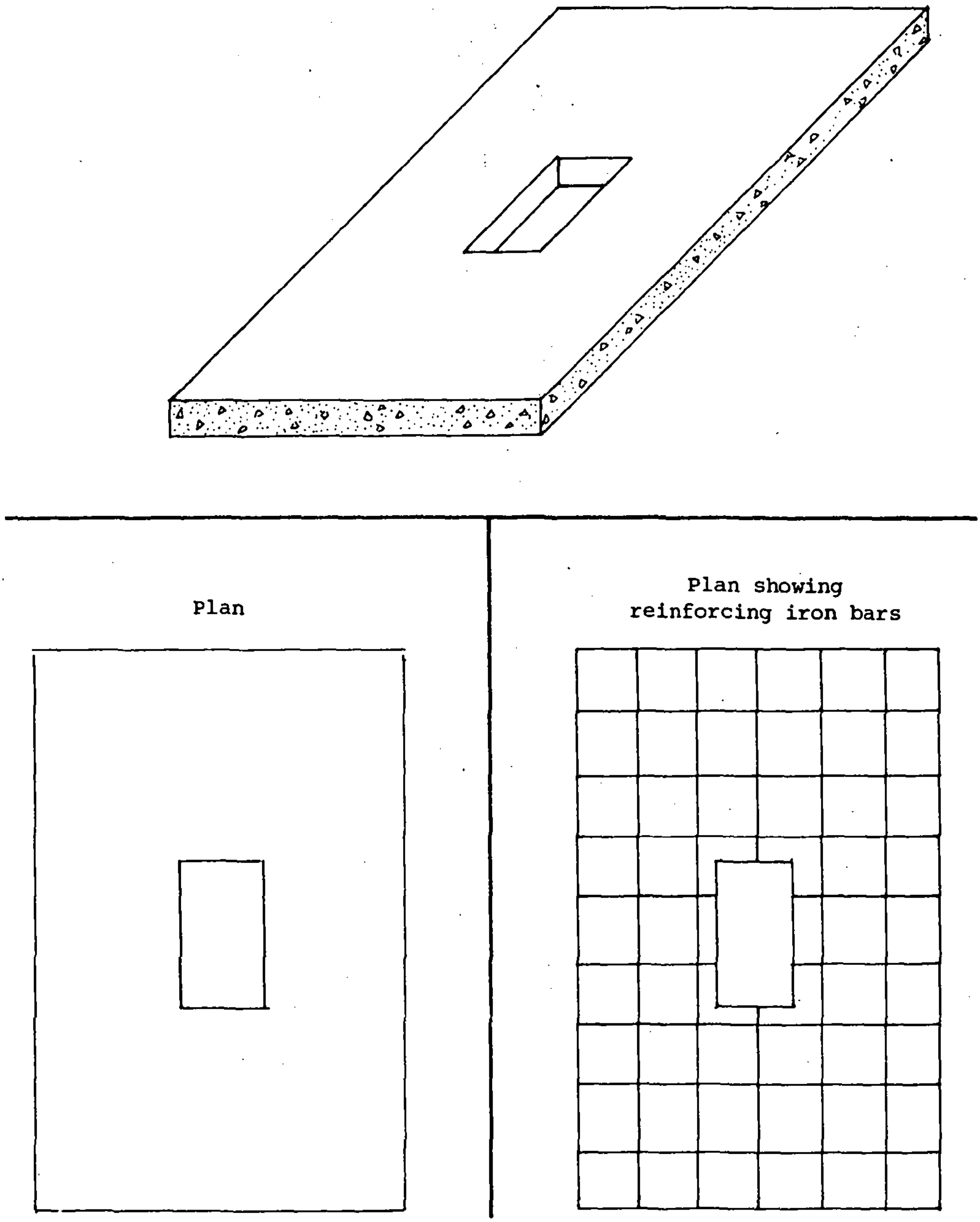


FIGURE 12. A squatting-slab made of concrete
(Scale 1 : 100)

Adapted from W.H.O. Monograph No. 39 (1958)



5. **Life of a pit latrine.** How long a pit latrine will last will depend on several factors, such as the depth of the pit, the number of users, the type of cleansing materials used, the rate of decomposition of the faecal material in the pit, etc. However, as a general guideline, it may be reckoned that a pit latrine 3 metres deep with a diameter of 80 centimetres will serve a family of six for about four years.

   When the pit is almost full (to about 50 cm below the level of the top), another pit should be dug on a different site, and put into use. The slab and superstructure should be removed from the abandoned site, to be transferred to the newly constructed pit. Before it is installed, the slab should be carefully washed and dried (if possible with a disinfectant such as chlorine water).

   The former pit should be sealed before it is abandoned. The top part of the partly filled pit should be covered with clean, dry earth or ashes, and packed hard to about 40 cm above the surrounding level. In order to prevent animals (dogs, etc.) and children from digging or playing there, the abandoned pit should be covered with heavy stones, brushwood or logs.

   When a pit latrine is almost full, the family is advised to contact the sanitarian, health assistant or community health agent from the nearest health institution, and ask advice about constructing the new pit latrine and how to seal off the old one.

   It should be mentioned that in Addis Ababa, and probably in many other cities of the Third World, town-dwellers have run out of space for new latrines. Accordingly, a pit latrine cannot be sealed off when full, but must be "desludged"; that is, the sludge or waste matter must be sucked out by a vacuum truck or removed by other means.

6. **Maintenance.** It is absolutely essential that the latrine should be kept clean at all times. The immediate surroundings of the latrine should not be fouled with faeces or urine, because this will create a nuisance and discourage the proper use of the latrine. The cover should always be kept over the hole when the pit is not in use, in order to eliminate fly-breeding and foul odour.

   Pouring of disinfectants or lime into the pit should not be done, as this will kill the bacteria which are responsible for the decomposition and reduction of the faeces.

7. **Advantages of a pit latrine.**
   (a) If constructed according to the specifications described in this text, and if properly used and maintained, the pit latrine will satisfy the basic objectives of correct excreta disposal.
   (b) It is reasonably easy to construct a pit latrine with locally available tools. This is one of the cheapest systems of sanitary excreta disposal.

8. **Disadvantages.**
   (a) Pit latrines are usually suitable for rural areas where people live in scattered houses, with plenty of open spaces. They are not recommended for towns, where people live in crowded situations, on relatively small plots of land.
   (b) Pit latrines normally cannot be constructed in places where the ground formation is too rocky for digging. Moreover, pit latrines cannot be used in places where the water table is very high (near to the ground surface), and particularly not where shallow wells are the source of water supply, since these wells will become contaminated.

9. **Cost of a pit latrine.** It is rather difficult to make an accurate estimate of the cost of a pit latrine, because the cost is influenced by several factors such as the place, the quality of the pit latrine desired, the soil formation and steepness or flatness of the locality, the type of local building materials available, cost of labour, etc. However, to give a

rough idea to the reader, the estimated cost of a pit latrine (in Addis Ababa in 1980 G.C.) with dimensions 2m × 1m × 3m, and with walls and roof constructed with corrugated iron sheets, and the floor with a reinforced concrete slab, was around Birr 202 (1 birr = 0.50 U.S. dollar). (See Table 9.)

On the other hand, if the wall and roof were constructed with timber and thatch (grass covering), instead of with corrugated iron sheets, the cost was around Birr 142.

Assuming that the lifespan of a pit latrine is four years for a household of six persons, the capital cost per head was then about 8.40 Birr or 5.90 Birr respectively, or about 70 or 50 cents per month, respectively. On the whole, the per capita cost was much less in the rural areas of the country.

TABLE 9. Specification and rough estimation of costs for the construction of a pit latrine in Addis Ababa (1980 G.C.) (Wall and roof made of corrugated iron sheets)

Item	Specification	Unit	Quantity	Unit price (Birr)	Total price (Birr)
1	Excavation of pit (2x1x3)	m	6	4.00	24.00
2	Reinforced concrete slab (0.06 x 0.6 x 0.9m) with 15 x 20cm hole	m	0.0324m³	450.00	14.58
3	Base, 4 logs 200cm and 2 logs 300cm in length, 10cm diameter, on top of pit latrine	each	6	2.00	12.00
4	Tree limbs of 4cm diameter to cover the floor of the pit each side of the slab	each	2 bundles	2.00	4.00
5	Standing logs 8cm diameter, 250 cm height	each	6	2.00	12.00
6	Wood for fastening the corrugated iron sheet walls	each	5	0.50	2.50
7	Wall of corrugated iron sheet including door of the same material, 35 gauge	each	5	9.00	45.00
8	Wooden frame for fastening the roof, 200cm length and 6cm diameter	each	5	0.75	3.75
9	Roof of corrugated iron sheet, 35 gauge	each	2	9.00	18.00
10	Simple hole-cover made of strong plain board 20 x 20cm, with 50cm height handle	each	1	2.00	2.00
11	Nails, assorted, 6, 8, 9, 10cm	kg	1	2.50	2.50
12	Nail crown 6, 8, 9, 10cm	kg	½	6.00	3.00
13	Hinge	each	2	1.00	2.00
14	Bolt	each	2	1.50	3.00
15	Labour for carpentry work, and for finishing mound surrounding the pit with compact or compressed earth				30.00
16	Termite-proof paint				5.00
	Total				183.33
	Contingencies 10%				18.33
	Total				201.66

Source of information: Division of Environmental Health, Ministry of Health, Addis Ababa.

4.3 THE DEEP TRENCH LATRINE

As the name indicates, the deep trench latrine is a variation of the pit latrine, dug in the form of a trench, trough or ditch. It is dug in one horizontal level. A deep trench latrine may be used in army camps of the semi-permanent type, in settlement sites, work camps, etc., where many people live in a communal way of life.

One unit of a deep trench is normally 60 to 90 cm wide, with a minimum depth of 2 to 3 metres and a length of 3 metres. A trench of this length will provide apertures or openings for five slabs, each 60 cm × 60 cm. Each aperture can serve the needs of 15 to 20 persons. If there is a bigger number of people, the number of seats can be increased proportionately by increasing the length of the trench by 60 to 90 cms for every 15 persons, or by constructing as many trenches as needed.

The depth of the trench is regulated by the level of the ground water. In an area where well-water is the source of water supply, at least 45 cm of earth should be left between the ground water level and the bottom of the trench. In areas where the ground water table is low, the depth of the trench should be 4 to 6 metres, in order to prolong the life of the trench latrine.

After the digging of the trench is accomplished, the sides should be constructed with stone lining, if stones are available, or with bricks, concrete hollow blocks or seasoned, well-dried timber frames, in order to prevent the sides from collapsing. Then slabs (preferably concrete slabs) should be placed over the strong supports at the sides of each aperture. In the same way as explained earlier in this chapter, a superstructure made from any locally available material can be installed over each trench to provide privacy.

It is important that each set or opening should be provided with a tightly fitting cover, which should always be kept in position when the latrine is not in use. Pouring any type of disinfectant down the aperture must be avoided, as this will interfere with the natural processes of decomposition of the excreta, with the help of bacteria.

Since a deep trench latrine is a communal system, it is absolutely essential that each user should be disciplined to keep the latrine clean, and to replace the cover of the slab after each use. Before constructing this type of latrine, ways of teaching and carrying out the proper use and maintenance should be considered as an essential factor, otherwise the trench latrine will be a place for fly-breeding and foul smells, defeating two important purposes of proper excreta disposal.

When the contents of the trench reach to within about 60 cms of its top, the support, slabs and superstructure should be moved to another trench prepared ahead of time, and the old trench should be carefully sealed off and abandoned. Sealing should be done by covering it with dry earth and packing it down, and then covering it with rocks, as described under *Pit latrine.*

4.4 THE BORED-HOLE LATRINE

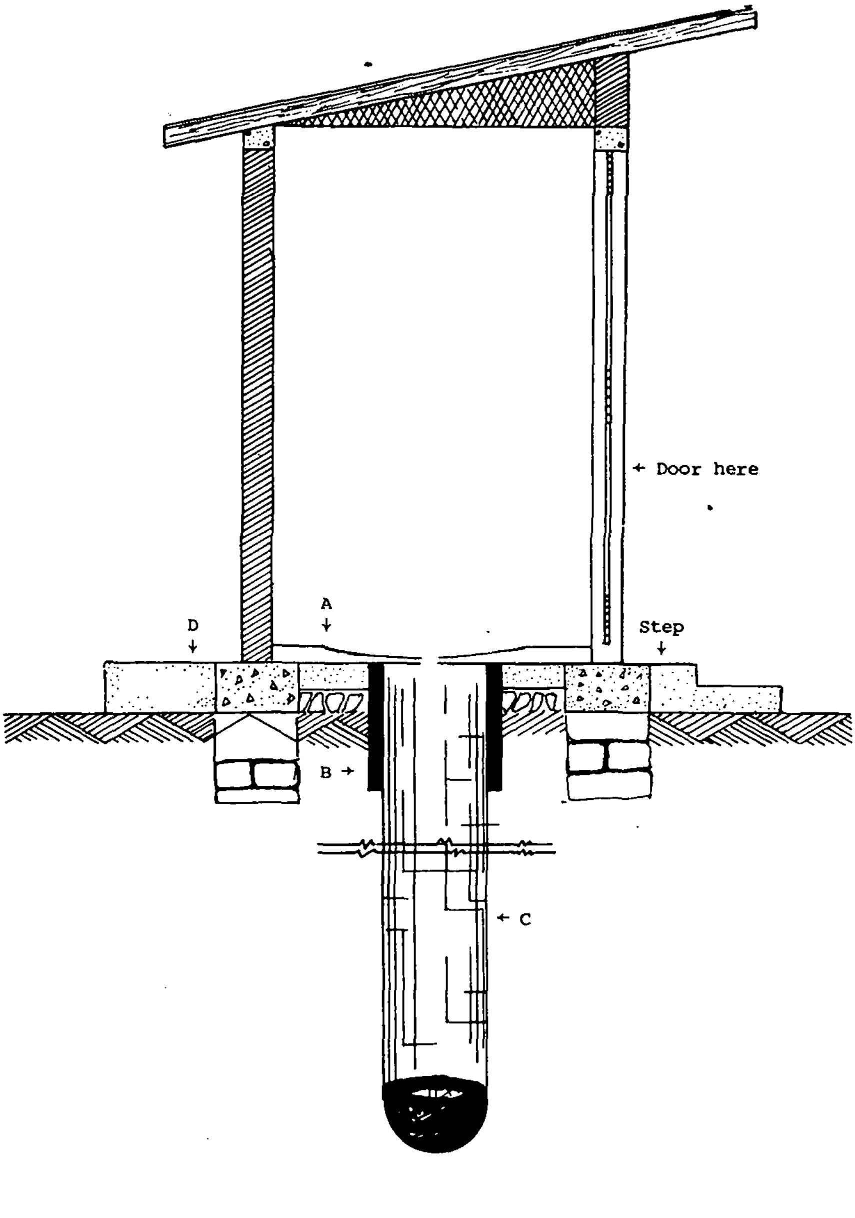
The bored-hole latrine is a modification of the pit latrine. It is excavated or dug out by means of specially-made boring equipment known as the "earth auger" or simply an auger. An auger is a screw-like tool, with its diameter varying from 30 cm to 45 cm, and with its length adjustable to any desired depth.

To excavate, the earth auger, fitted with a guide board to make sure it makes a straight vertical bore, is placed in the desired location, and digging is performed vertically downward until the appropriate depth is reached. In a bored hole, the depth varies from a minimum of 4 m to about 8 m or more.

When boring is complete, a concrete slab with the usual supports and cover is placed over the bored hole. Superstructure, similar to that of a pit latrine, may be installed for privacy (Figure 13). Since the diameter of the auger is small, the life of the bored hole latrine

FIGURE 13. A typical bored-hole latrine

(Scale 1 : 20)



A : squatting slab with sides sloping towards the hole

B : impervious (watertight) lining of clay tiles

C : lining of woven bamboo, to let the effluent seep through

D : earth mound, well tamped down or packed

Adapted from W.H.O. Monograph No. 39 (1958)

is relatively short, depending on the number of users, and whether they use, for example, maize-cobs or stones to clean the body after defaecation; such materials will quickly clog the latrine.

1. **Advantages.** The bored-hole latrine is constructed quickly and easily; hence a large number can be completed in a short time.
2. **Disadvantages.** The disadvantages are usually greater than the advantages of a bored-hole latrine:
   (a) The earth auger is a specially designed tool which may not easily be available everywhere.
   (b) Boring can be done only in places where the nature of the soil is suitable. This technique cannot be applied in places where the subsoil is rocky.
   (c) A bored-hole latrine should not be constructed in places where the ground water table is high, especially if the sources of water supply are shallow wells.

Certainly the bored-hole latrine has a very limited use in Ethiopia. It is described here only to show that there are various types of excreta disposal systems, from which a choice can be made to fit local conditions.

4.5. THE COMPOST LATRINE OR DOUBLE-VAULT LATRINE

The term "to compost" means to transform organic wastes such as garbage, human excreta, animal manure, etc., into stable humus or fertilizer. Composting is a biological process which is brought about by various forms of organisms - aerobic and anaerobic bacteria, fungi, etc. An example of nature's method of composting can be observed in thick forests, where fallen leaves and other vegetable and animal remains are turned into humus. But nature's method of composting is a very slow process, and not very reliable.

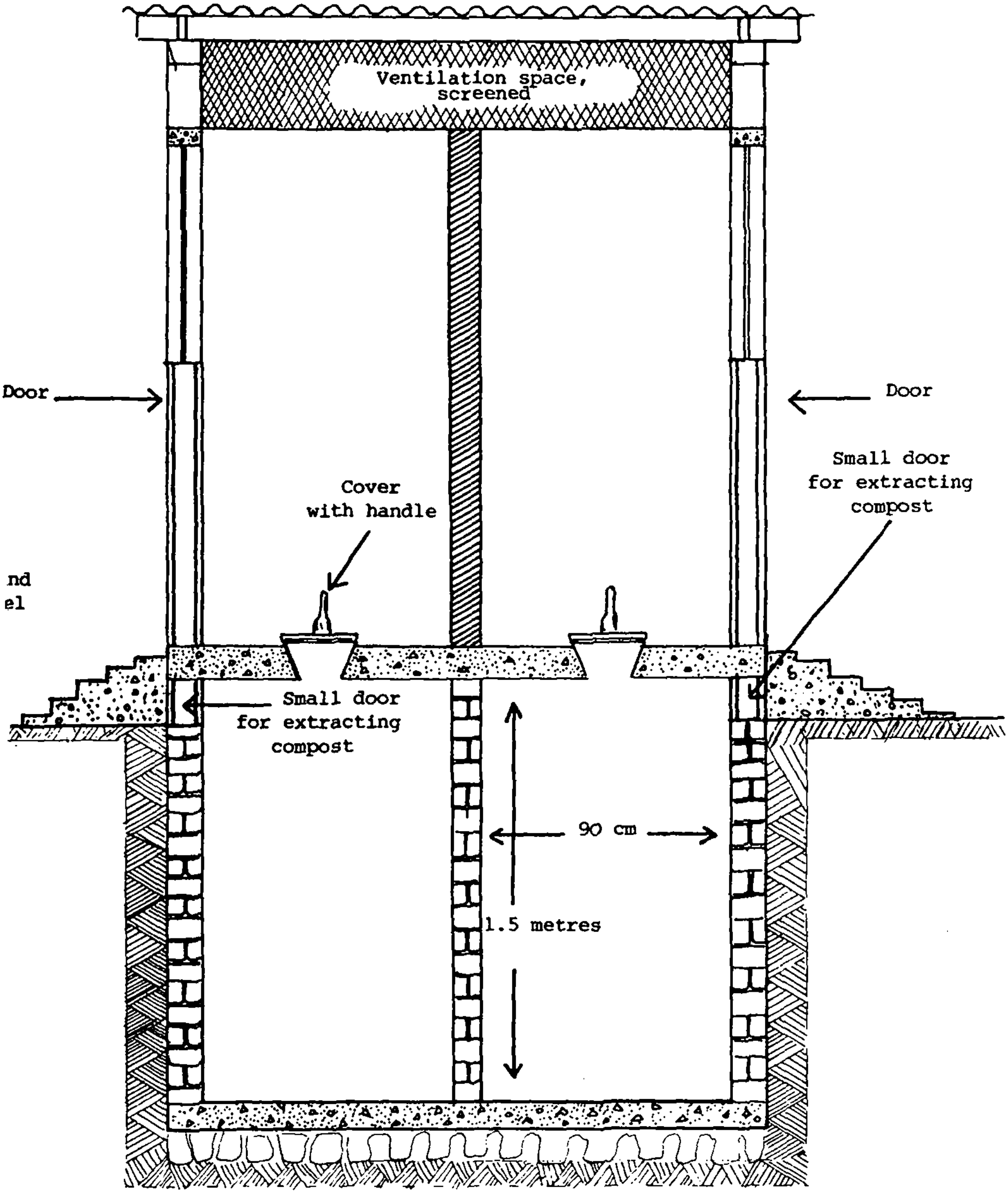
Man has imitated nature's method of composting, and adapted it to take place under controlled and faster conditions. In China and some other Far Eastern countries, the practice of composting human excreta for use as a fertilizer has been established for centuries. If properly practised, disposal of excreta by the composting method has a double advantage: it prevents excreta-borne diseases, and it provides compost, which is a good soil fertilizer.

One of the simplest type of compost latrines, which can easily be constructed in rural Ethiopia, is the *double-vault latrine.* As the name indicates, a double-vault latrine is a latrine with two compartments. Each compartment is used alternately; that is, while one compartment is in use, the other is kept closed or sealed.

Construction of a double-vault latrine

The method of constructing a double-vault latrine is quite simple (Figure 14). A pit is dug, 1.80 metres wide, 1.50 to 2.50 metres deep and 1.20 m long. Then the pit is divided into two equal compartments, each being 90 cm wide. The pit and the partition wall can be constructed with stone or concrete block. Each compartment is fitted with the usual squatting-slab, and a superstructure is built over the entire pit. A small back-door is usually made for taking out the compost. After completion, one of the compartments is used just like a pit latrine, while the second compartment is strictly kept closed. When the first compartment is filled to within about 30 or 40 cms from the top of the pit, the slab is removed to the second compartment, and that compartment is used. It is important that the contents of the compartment which is being abandoned should be levelled off with a long stick, and then covered with dry earth or ashes up to the top. It must then be sealed with heavy, unremovable material - a slab of wood or stone, or a corrugated iron sheet, - and left undisturbed for a period of 6 to 9 months. After 6 to 9 months, the compost can be shovelled out

FIGURE 14. A compost or double-vault latrine



by the back door and used as fertilizer. During this period, the second compartment is used. It should be noted that the contents of the vault-latrine are mostly solid, or only semi-liquid, because only urine with faeces is deposited in the vault, and most of the fluid seeps away through the rough walls of the pit to the surrounding ground. Hence it will not overflow or spill out when it is being sealed off.

The site

The siting of a compost latrine in relation to ground water follows the same rule as for a pit latrine. Especially in areas where the ground-water table is high, it is advisable to make the double-vault latrine watertight. This is done by plastering the side walls with mortar, consisting of lime and sand or of cement and sand. The proportion of cement to sand is usually 1 : 2, or 1 : 3 (that is, 1 part of lime or cement to 2 or 3 parts of sand). This is thoroughly mixed with water, and the mixture is used for plastering the side walls.

The size

The size necessary for a double-vault latrine depends on the number of people using the latrine, on the needs for fertilizer, and on whether organic wastes other than human excreta (such as garbage, animal manure and vegetable remnants) will be added to the pit or not. As indicated earlier, the transformation of human excreta into compost is brought about through a biological process, which is anaerobic decomposition in the case of a double vault latrine. Therefore, suitable conditions should be created for this process, such as preventing the entrance of floodwater, avoiding adding too much fluid, sealing off the filled compartment for the period of 6 to 9 months, not using the two compartments simultaneously, etc.

It is believed that, if a compost pit is properly operated, all forms of pathogenic organisms, such as bacteria, and the eggs of protozoa and helminths, are completely destroyed in it. In a correctly operated pit, the temperature generally reaches 60°C to 70° during the decomposition period, and it is the heat that is mainly responsible for destroying the pathogens.

Since it is not customary in Ethiopia to use human excreta as fertilizer, the success of adopting a compost latrine will depend on the education and motivation of the rural farmers by health workers and agricultural extension cadres. It is advisable to introduce the compost latrine as a model project, so that its successful use and advantages can be seen and understood.

4.6. THE VIETNAMESE DOUBLE-VAULT LATRINE

Of all the public health measures designed after long years of research, and put into operation by the Vietnamese, the double septic tank has perhaps been the single most important factor in the prevention of disease and the promotion of health.

J.K. McMichael, *Health in the Third World: Studies from Vietnam.* 1976. Spokesman Books, London.

The Vietnamese model of the double-vault compost latrine is known as the *double septic tank* or *double septic bin*. Its full name is the *double septic tank for on-the-spot composting of excreta.*

In parts of Vietnam, in south-east Asia, it was a common practice to use fresh human excreta for fertilizing farmland, particularly rice-fields. Before the Vietnamese People's revolution, this practice, coupled with the habit of promiscuous defaecation, was responsible for widespread excreta-borne diseases - parasitic, bacterial and viral infections.

However, after the revolution, because of the introduction, popularization and persistent use of the double septic tank, along with the "curbed well" and "bathroom" systems, excreta-borne diseases are said to have been very greatly reduced.

Although the phrase "septic tank" is applied to the system, composting is brought about anaerobically in a dry state; that is, without the presence of liquid or moisture.

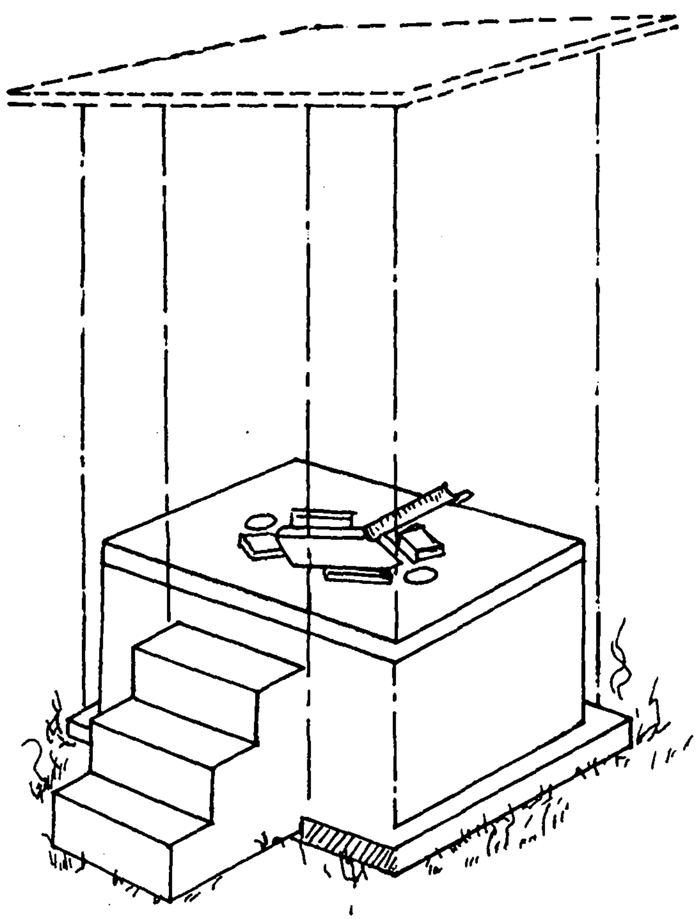
The Vietnamese double-vault latrine consists of a concrete vault, watertight and divided into two compartments which in turn serve for defaecation and for compost.

The vault can be constructed from locally available material built at least ten centimetres above ground level, and is made watertight. The dimensions recommended for a family of 5 to 10 persons is as follows: length 1.2 m, width 0.8 m and height 0.7 m.

The top part of each compartment is provided with a squatting-slab, with a hole in the middle for defaecation, with foot-rests, and with a groove or canal for draining away urine into a specially-designed urine-collecting jar (Figure 15a and b). In the rear of each

FIGURE 15a. The Vietnamese double-vault latrine, front view

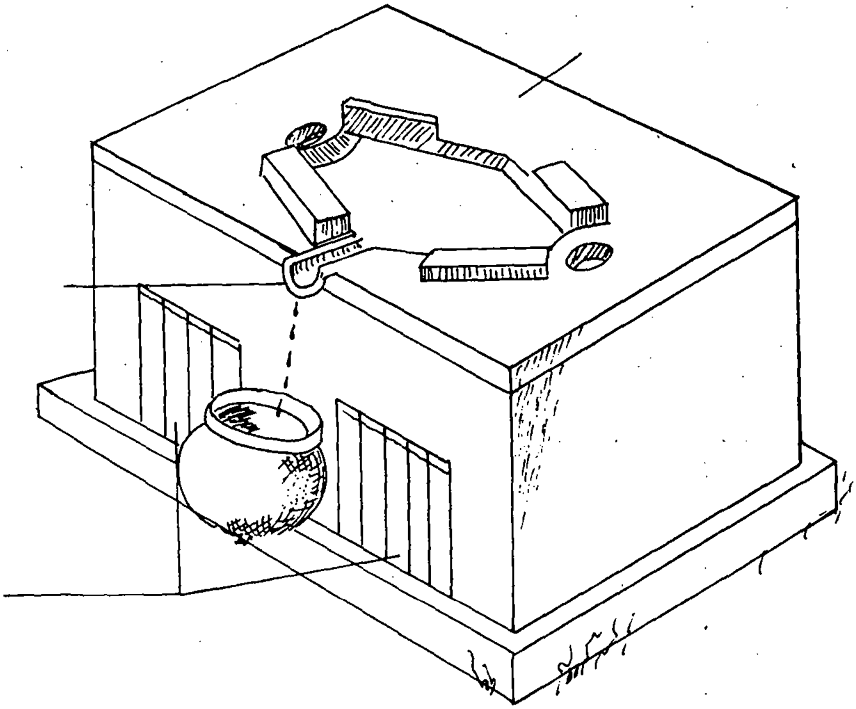
(Scale 1 : 25)



Reproduced from *Sanitation without Water* (1981), by U. Winblad

FIGURE 15b. The Vietnamese double-vault latrine, back view, showing urine-collecting jar and doors for compost withdrawal

(Scale 1 : 20)



Reproduced from *Sanitation without Water* (1981), by U. Winblad

compartment, a small door or opening, 30 cm by 30 cm, is installed, and sealed off unti the compost is ready to be taken out for agricultural use. The hole in the squatting-slat is always kept closed with a wooden cover, except during use.

Before the tank's use, the floor of the tank is sprinkled with ashes or dry earth ir order to absorb moisture and to prevent faeces from sticking to the surface.

After each use, ashes in a spade or scoop are always spread over the excreta, tc absorb moisture and to remove any smell.

When the compartment is almost full, the excreta are levelled off with a stick, ashe are spread over them, and the compartment is then sealed off. It is left undisturbed for 2 t 3 months, to make compost. During this period, the second compartment is put into use

According to Vietnamese experience, all forms of pathogenic organisms, includin eggs and larvae of intestinal parasites, are completely destroyed after 45 days, and the or ganic matters (faeces) are transformed into harmless humus or fertilizer.

Thus, the Vietnamese double-vault compost latrine serves two important purpose in a developing country where agriculture is vital: the sanitary disposal of excreta and th production of much-needed fertilizer. It is considered so important that the installatio has been developed for a mass country-wide campaign; the whole set can be manufacture in every part by using a ready-made mould into which a cement concrete mixture is pourec with the correct amount of water added. When the mixture is dry, the latrine is ready fc use.

4.7 THE AQUA PRIVY OR AQUA LATRINE

The systems of excreta disposal so far described under the non-water carriage systems are those in which excreta are directly deposited into a properly constructed hole in the ground. The aqua privy, literally meaning "water-latrine", differs from them, in that excreta are deposited into a tank that contains a fixed level of water. The tank is made watertight and is fitted with a drop-pipe or chute through which excreta drop into the water (Figure 16).

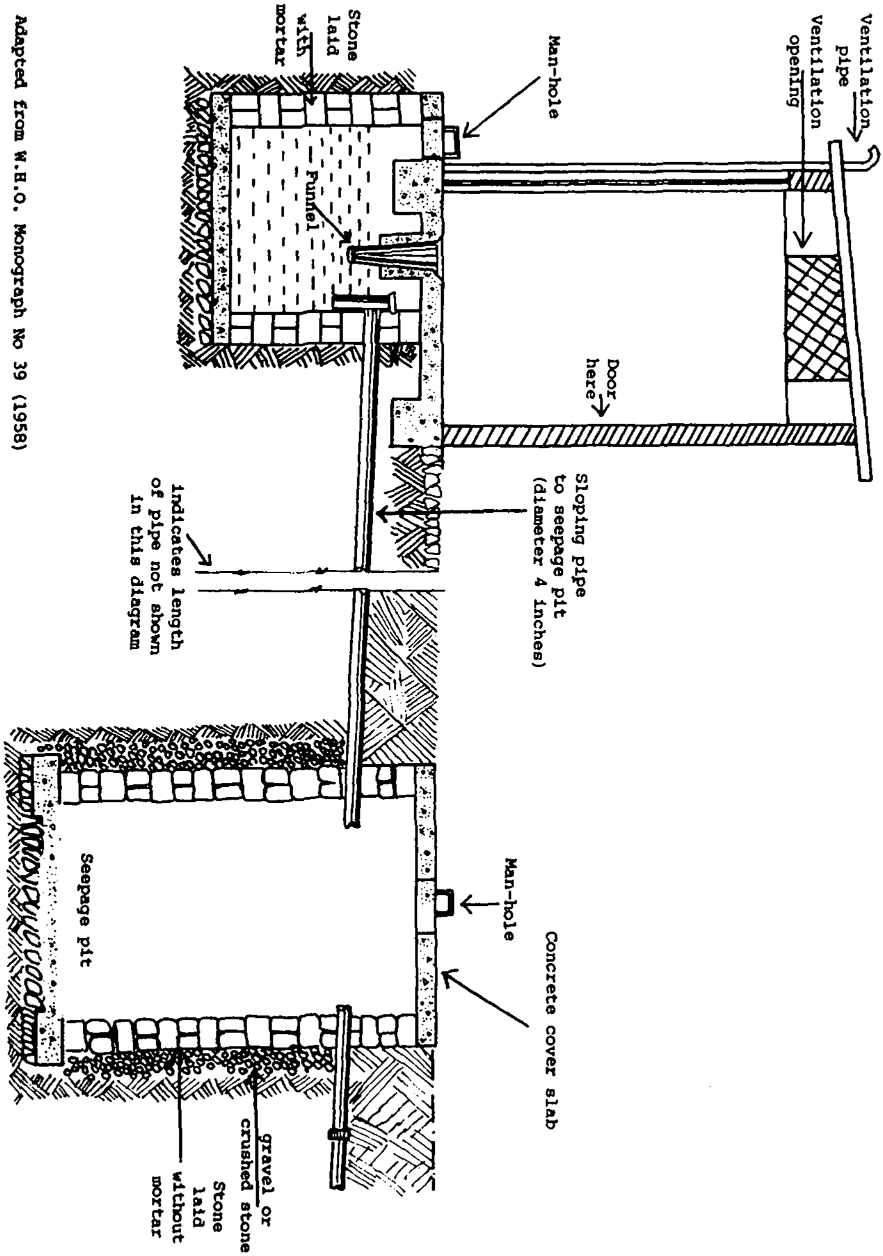


FIGURE 16. A family-type aqua privy (Scale 1 : 25)

Adapted from W.H.O. Monograph No 39 (1958)

Anaerobic digestion takes place in the tank, and as a result the excreta are reduced to about half of the original size, and are deposited at the bottom of the tank as sludge. The liquid portion, which is called effluent, is discharged into a seepage pit through the outlet pipe inserted in the tank.

An important feature of this system is the mass-produced drop-pipe, or funnel, which provides a water-seal barrier for preventing foul smells, fly-breeding, etc.

The drop-pipe attachment, made of materials which resist corrosion, such as cement, earthenware, or clay pipe, is generally 10 cm in diameter and descends to a minimum of 10 cm below the water level. Efficient functioning of the aqua privy depends on maintaining this level always at the same height, by pouring in water and desludging the digested excreta from the bottom of the tank at fixed periods of time, depending on the number of people using the tank, and the tank's size.

The tank is usually designed with a special method of desludging and with a vent or opening for the escape of gas, which is formed as the result of anaerobic decomposition.

It is essential that, after use of the latrine, one bucket of water (about 4 litres) should be poured in or "flushed" for each user per day. This means that an equal amount of effluent has to be disposed of through the outlet pipe into the seepage pit. Effluent disposal from the aqua privy has to be dealt with as in the septic tank system. (See Chapter Six.)

The size of the tank depends on the number of people using the latrine and the desludging period of the digested content (sludge). The size of tank for a family of ten, with an approximate desludging period of 4 to 6 years, is generally designed as follows: length 1.20 m, width 90 cms, depth 1.50 m, and an average liquid depth of one metre.

The size of the tank for communal use can be constructed proportionately on the above basis.

The aqua privy is more commonly used in communities where water is customarily available and used for all washing purposes. For further information, the reader is advised to consult some of the references listed at the end of the text.

1. **Advantages of the aqua privy**

   (a) If properly constructed and operated, the aqua privy satisfies the criteria set for proper excreta disposal.
   (b) It can be located near a dwelling-place, and can be used during the night with comfort.
   (c) It provides the advantages of a water-carried system with a limited amount of water needed, and without installing the flushing system and equipment.

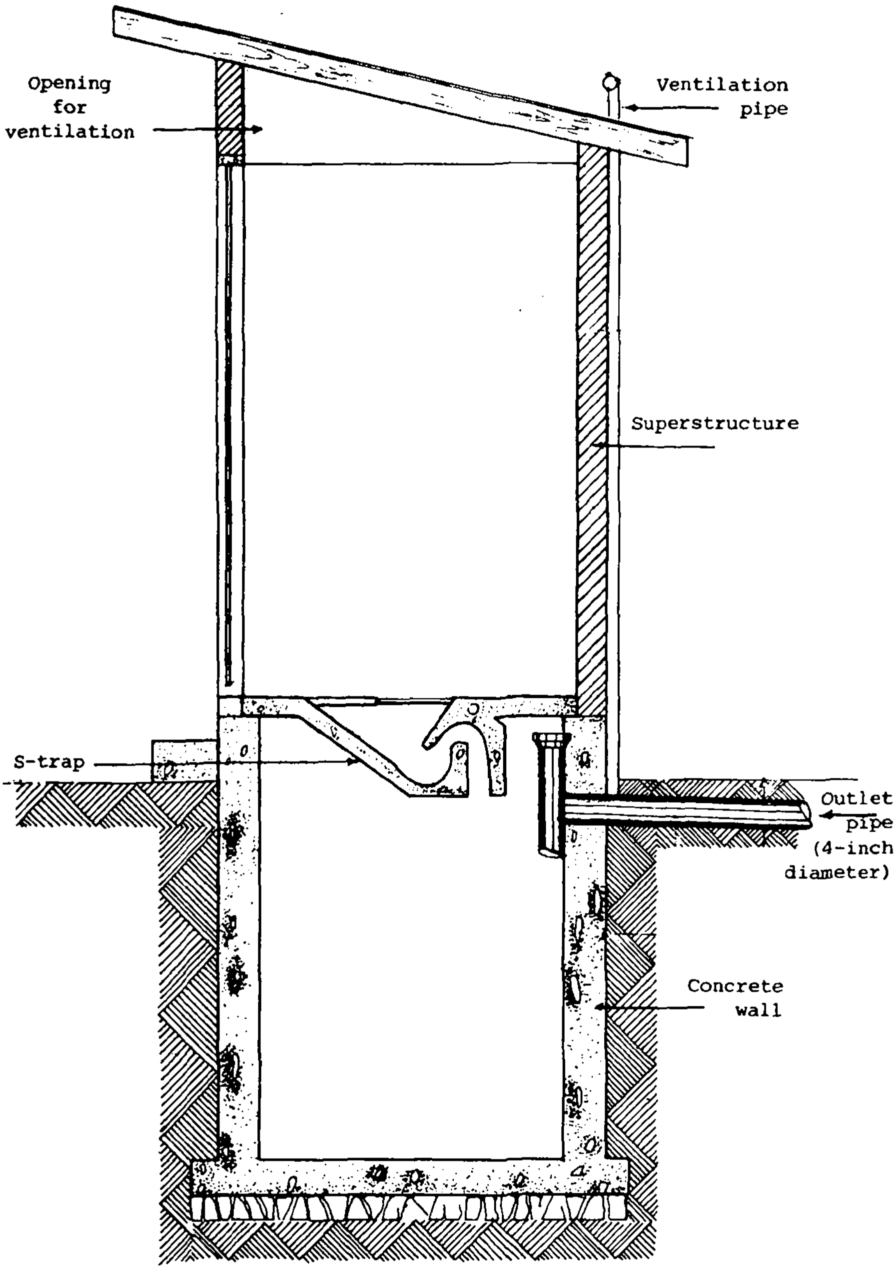
2. **Disadvantages**

   (a) The initial installation cost is relatively high.
   (b) The system constantly needs water, though only a small amount.
   (c) It entails the problem of effluent and sludge disposal.
   (d) It needs careful maintenance and supervision, daily flushing, periodic desludging, etc.

4.8 THE WATER-SEAL (POUR-FLUSH) LATRINE

The water-seal latrine is not basically different from the types of latrine so far described The essential feature which differentiates it from other systems is the specially designec squatting-plate with a trap attachment which retains water (Figure 17). The squatting-plat is generally made from cement elements in a standard size.

FIGURE 17. A water-seal latrine



Adapted from W.H.O. Monograph No. 39 (1958)

The squatting-plate, with its trap attachment, may be installed over a pit latrine, bored-hole, aqua privy or a septic tank. Or it can be installed inside the house, and is then connected to an absorption pit or septic tank through a drain-pipe fixture.

A jug or pail of water is kept in the latrine shelter. After depositing excreta through the hole in the squatting-plate into the pan, each user pours water (at least a litre) from the jug into the pan, and so the name "pour-flush" latrine is used. The excreta are flushed through the pipe into the pit by the water, but some water remains in the trap in the S-bend and seals off the pit; this gives the name "water-seal" latrine. The water in the trap has a depth of from 1.25 cm to 4 cm. Its function is to stop flies and other vermin from entering the pit, and to stop the escape of foul smells from the pit or tank to the house.

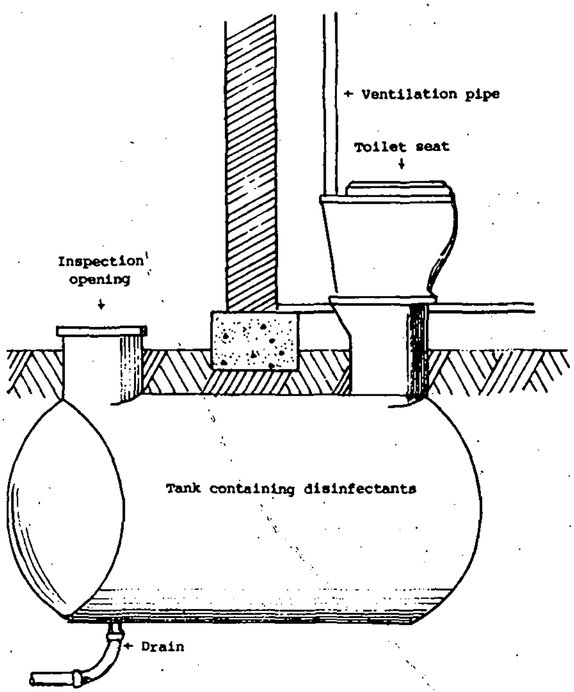
For efficient functioning, it is essential that from one to three litres of water is poured into the trap after each use, and that the jug or pail holding the water is constantly refilled. Note that, though water is used in this method, the water-seal latrine is not a water-carriage method of excreta disposal.

For further details, the reader is advised to refer to some of the references listed at the end of the book.

4.9 THE CHEMICAL TOILET

The chemical toilet is a type of latrine which contains a solution in water of a chemical disinfectant in a specially designed tank. The tank is designed with the usual toilet seat with cover, flushing device and a discharge drain for bailing out the contents when the tank is full (Figure 18).

FIGURE 18. A chemical toilet
(scale 1 : 30)



Adapted from W.H.O. Monograph No. 39 (1958)

Excreta are directly deposited into the solution of chemical disinfectant. The disinfectant causes the excreta to break up, and destroys all micro-organisms, both pathogens and non-pathogens, including the eggs of parasites which might be present in the excreta. Usually the chemical toilet tank is installed with a device for stirring up the excreta deposited, to make thorough disinfection easier.

The chemical disinfectant normally used is caustic soda or sodium hydroxide, dissolved in a pre-determined amount of water. To this solution, a small amount of cresol, or phenol or other carbolic acid derivates, and a few millilitres of crude oil are added. The caustic soda breaks up and sterilizes the excreta; phenol disinfects, and also prevents foul smells; while crude oil minimizes splashing during use of the toilet.

When the tank becomes full, the contents are discharged through a drain which is fitted to the tank. The tank is refilled with disinfectant for further use.

Tanks for chemical toilets are commercially made, with different capacities.

Chemical toilets are generally used in aeroplanes, trains, boats, trailers or motor caravans, etc. They can be used also in isolated houses, in seasonal vacation resorts, at construction sites, etc.

The chemical toilet tanks may be movable or non-movable. Non-movable ones, usually installed in a house, are made of about 500-litre capacity. For this capacity, around 10-15 kilograms of caustic soda dissolved in about 50 litres of water makes up the disinfectant component of the tank. The movable types are of smaller capacity, usually of about 40 litres, and the amount of chemical disinfectant is determined proportionately. This is the type of tank usually used in aeroplanes, boats, trains, etc., and the contents of the tank are emptied into a truck and removed to a septic tank, sewer or cesspool at the end of a specified journey. The portable tank is then refilled with disinfectant for further use.

1. **Advantages.** This type of latrine is well suited for special circumstances, such as in an aeroplane, or caravan. It is efficient and comfortable, and satisfies the criteria set for proper excreta disposal.
2. **Disadvantages.** A chemical toilet is very expensive for initial installation, as well as during operation. The specially manufactured, strong, corrosion-resistant tank may not be easily available even at a high price. The cost of disinfectant used is beyond the means of the average man.

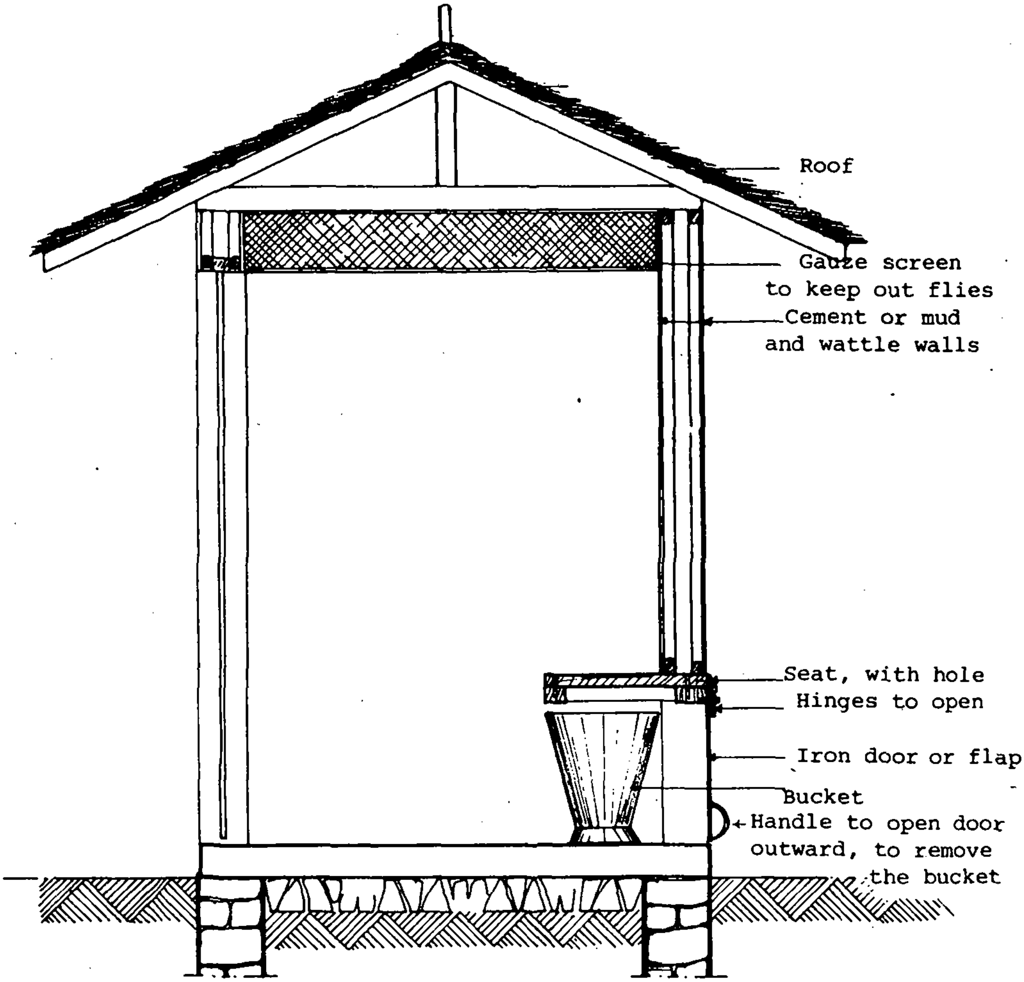
Although the high cost limits the wider use of a chemical toilet, it is worth noting that different alternative methods for proper excreta disposal are available to suit various conditions.

4.10. THE BUCKET OR PAIL LATRINE

Before we conclude the non-water carriage systems of excreta disposal, we should mention the bucket latrine system, though noting its disadvantages.

In this method, the excreta are deposited into a properly constructed movable bucket or pail. The usual squatting-plate or concrete slab seat and a superstructure are generally installed over the bucket, and a pile of dry earth, ash or sawdust is kept nearby, and employed to cover the excreta after each use, to discourage flies and reduce smells (Figure 19).

FIGURE 19. A bucket latrine
(scale 1 : 20)



Adapted from W.H.O. Monograph No. 39 (1958)

A small external door is provided in the superstructure, to remove the bucket when it is full. A second bucket is needed to replace the first. Where the bucket latrine system is in common use, the full buckets are removed by sanitary workers employed for the purpose, loaded into carts or lorries, and taken to a disposal site, where

(a) composting is done,
(b) burial of the excreta (called night-soil) takes place in pits or trenches, or
(c) dumping into sewer-lines takes place.

The empty buckets are washed with water under pressure, and disinfected before being returned to their place, at 24-hour intervals. The work is done under strict supervision, otherwise the spread of disease is likely.

In some areas, night-soil has been known to be dumped into rivers, lakes, the sea, etc., an unhygienic practice which has led to the dangerous pollution of those areas.

It can be seen that the efficient working of this system requires, among other things, a dedicated staff of labourers for an unpleasant job. It is not easy to provide such a staff and ensure hygienic disposal of night-soil, and without these factors the use of bucket latrines should be discouraged.

In concluding this chapter, it should be noted that several of the alternative methods of the non-water carriage system discussed are economically and technically more appropriate to the Ethiopian situation and to the situation in other similar developing countries than the modern water-borne sewerage system.

However, the choice of a specific technology depends upon local conditions, such as acceptability, capital cost, operation, and maintenance (Table 10).

TABLE 10. Comparative cost and suitability of various non-water carriage systems

Type of System	Suitability		Cost		Manpower requirement		Water requirement
	Urban	Rural	Capital	O & M	Constr.	O & M	
Pit latrine	+	++	1	1	1	1	0
Bored-hole latrine	+	++	1	1	1	1	0
Double-vault latrine	+	++	2	1	2	1	0
Vietnamese double-vault latrine	+	++	2	1	2	1	0
Aqua privy latrine	+	++	3	2	3	2	1
Water-seal (pour-flush) latrine	++	+	3	2	3	2	2
Chemical toilet	++	+	4	4	4	4	3
Bucket latrine	++	+	1	3	1	3	0

+: poor
++: good
O & M: operation and maintenance
Constr.: construction

0: none
1: low
2: medium
3: high
4: very high

CHAPTER FIVE

THE WATER CARRIAGE SYSTEM

The water carriage system of human wastes disposal is a system in which the excreta are deposited directly into a properly constructed *sanitary fitting* or *sanitary appliance* and then immediately carried away by water through a network of piping called *drains* and *sewers* to the final disposal location.

The practice of collecting human wastes from individual houses through a network of underground drains or sewers, and of the sanitary disposal of the resulting sewage, has been in use in the big cities of the developed and industrialized countries for many years. Consequently, the design, production, and installation of sanitary fittings, piping system (sewers), and the method of treatment of the sewage have been standardized in most countries of the world where the system is in use.

As the name implies, a large quantity of water under pressure is used to remove the excreta from dwellings. Water is primarily used as a transporter, and becomes itself contaminated in the process.

Normally the water carriage system depends on the following:

1. The installation of a piped water supply in houses
2. The installation of sanitary fittings or appliances inside the houses, to receive excreta and waste-water (both at times called waste-water)
3. The construction of a network of connecting pipes (house-drains, sewers, etc.,) to collect sewage from individual houses in a neighbourhood, and to convey it to the final disposal site.

In a community or a city where the sanitary status has been well developed, all the three stages go together; the installation of a water supply in a house without providing means for disposal of the resulting waste-water does not create a healthy environment.

The process, the activity of fitting up the system, and the piping system, which combines the three stages (furnishing water supplies to houses through a piping system, and removing the resulting sewage or spent water through a network of drains, sewers, etc.), is called *plumbing*, from the Latin word *plumbum*, meaning the mineral lead. Some pipes are still made of lead, which resists corrosion by rust, etc.

Plumbing applied to a water supply system is called *supply plumbing*, whereas that which is applied to waste or sewage plumbing is known as *waste plumbing*. Each system has standardized and well-defined rules, and is carried out by skilled and certified technicians.

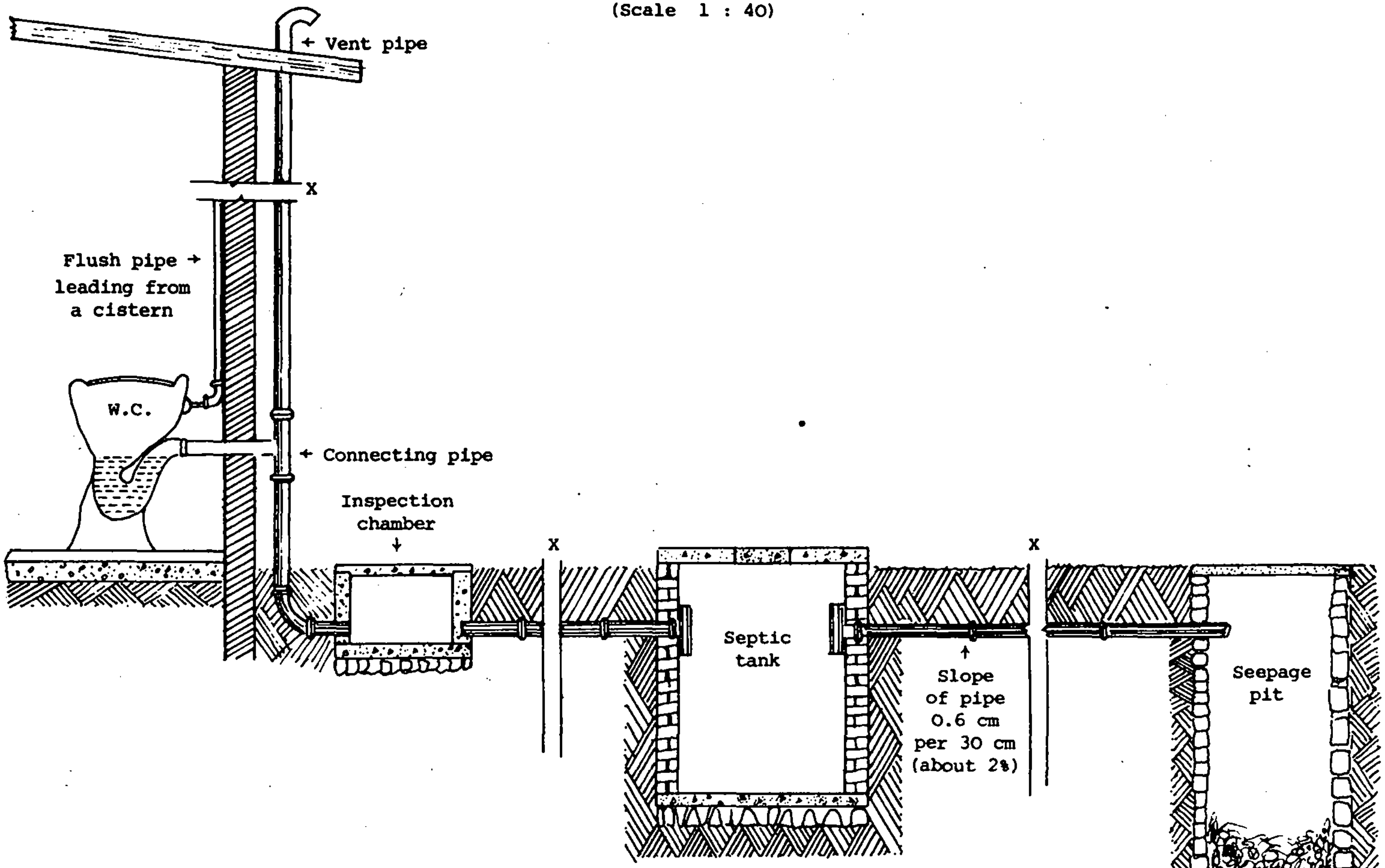
5.1. TYPICAL SANITARY FITTINGS OR APPLIANCES USED IN THE WATER CARRIAGE SYSTEM.

The water closet (W.C.)

The water closet, popularly known in its abbreviated form, the W.C., is a device for depositing human wastes directly into a properly designed bowl or pan. Then the excreta are immediately carried away by water which is flushed under pressure. These pans are designed with a connection for flushing water under pressure (Figure 20).

FIGURE 20. Typical lay-out of a water-carriage system

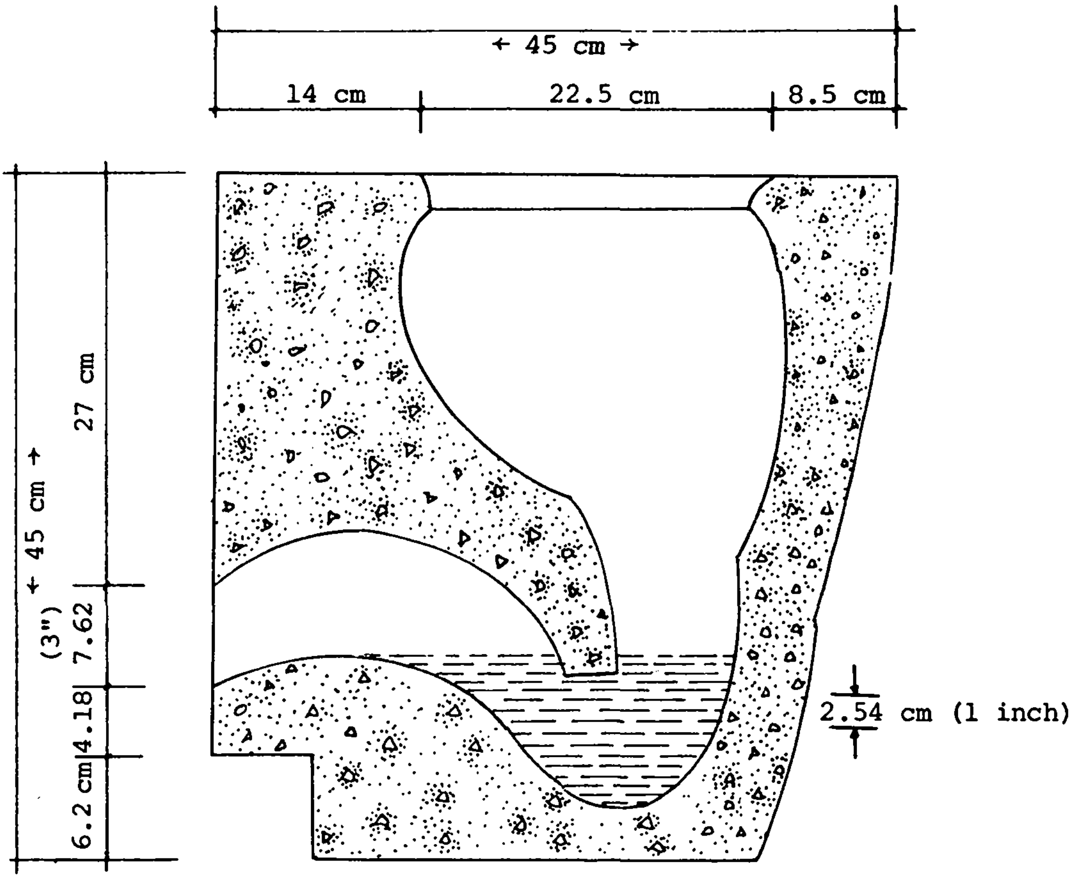
(Scale 1 : 40)



"X" indicates a length of pipe not shown in this diagram.

An important component of a W.C. pan is the "trap" or bend provided, shaped like an "S" or a "P", for retaining a fixed amount of water after the excreta have been flushed away into the drain-pipe to a final destination. The water retained in the trap is called the seal. Its purpose is to prevent foul-smelling gases from escaping into the room from the drainage system, and to eliminate the danger of flies and other insects entering into the space below. The seal is designed in such a way as to retain, automatically, water of a depth of 2.54 centimetres after each flush (Figure 21).

FIGURE 21. Reinforced concrete pan and P trap cast in a single unit

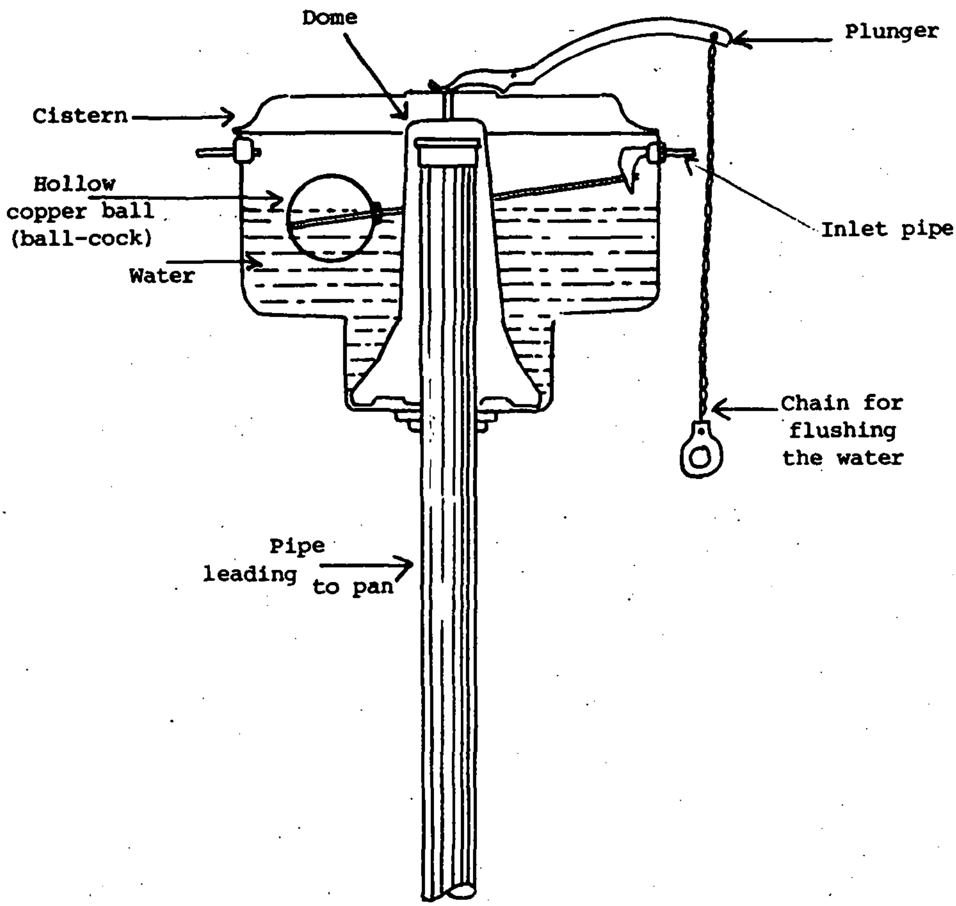


Water closets are generally of two types: those which are made to be used in a sitting position and those made to be used in a squatting position. The latter are usually called oriental or squatting-system W.C.s. This type is generally installed in hospitals, schools or similar institutions, where the W.C.s are constantly used by many people. The advantage claimed for these types is the prevention of lice, skin diseases and venereal diseases which might possibly be contracted from the sitting type.

The flushing cistern

The flushing cistern attachment is designed to release a predetermined quantity of water under pressure in order to flush away excreta from W.C. pans or urinals. The flushing cistern is connected to the pans or urinals by a flush pipe, and water is released under pressure by pulling a chain or handle attached to the cistern (Figure 22). A "standard" toilet requires from 20 to 30 litres of water for each flushing. In the case of modern public urinals, a predetermined quantity of water is released automatically at fixed intervals.

FIGURE 22. A flushing tank



The lavatory

Lavatories or wash-hand basins are used for the washing of hands and face. These, like other sanitary fittings, are designed in a standard form, and various makes are found on the market. They are usually made of glazed earthenware or porcelain. At the bottom they are connected to the waste-water discharge pipe. Since the room containing the wash-hand basin often contains a W.C., the W.C. is often called the lavatory.

Bath tub and shower

A modern bathroom is provided with a bath-tub and/or a shower for washing the body. Here again the bath is designed in a standard form and shape. A typical bath is oval-shaped, made of glazed earthenware or enamelled cast iron. It is provided with a discharge hole controlled by a stopper or plug and chain, and fitted with an overflow device, in case the water is accidentally left flowing into the bath. Hot and cold water faucets or taps are fitted for filling the tub. Showers may be installed together with the bath-tub or separately.

The bidet (French word, pronounced bee-day)

A bidet is an oval-shaped sitting-pan provided in some houses and fashionable hotels by the side of W.C.s and bath-tubs. The bidet is not an essential component of bathroom fittings. It is provided for the purpose of intimate washing, especially for women. It is furnished with hot and cold water, and can produce an upward spray as desired.

The sink

Sinks are large basins permanently installed in kitchens for washing dishes, pans, etc., and for cleaning vegetables, etc. Sinks are provided with stoppers for keeping water in them, and with an overflow device. They are connected through traps to the waste-water discharge pipes. Another sanitary fitting commonly found in a modern house is the laundry facility, 'or washing clothes. It is usually a large sink, or two large sinks side by side, for washing ınd rinsing out soap.

The main purpose of describing the above sanitary fittings is to familiarize the reader 'ith the various sources of sewage or waste-water.

From the point of view of public health, we can divide sewage into two forms: a) sewage originating from the W.C.s and urinals, which is in actual fact sewage - human :xcreta, faeces and urine mixed with a large quantity of water; and (b) the discharges of ıvatories, sinks, bath-tubs, laundries, etc., which are dirty water mixed with soap or deter- 'ent powder. The used water from those sources is normally called waste-water, gray water, r sullage water. But since these waste-waters and the discharge from W.C.s and urinals re disposed of through the same drainage system and sewers, they are all called "sewage", r sometimes waste-water or simply wastes. Thus sewage is usually defined as all liquid astes, from W.C.s, urinals, bathrooms, kitchens, sinks, laundries, etc.

In order to have a clear picture of how human excreta are disposed of through a water ırriage system, we shall take a close look at Figure 20 and follow the process.

Excreta are deposited in the W.C. pan and immediately flushed away. The ixture of water and excreta, now sewage, is carried away through the trap and drain pe and connecting pipe, under the inspection chamber or manhole, and into the sewer a predetermined self-cleansing speed to a disposal point, which may be a cesspool or a ptic tank, or another form of disposal.

In a similar manner, sewage (all liquid wastes) from several houses or dwellings is nnected to the disposal site through a network of piping.

5.2 CHARACTERISTICS OF DOMESTIC SEWAGE

Domestic sewage, that is sewage from residential areas (excluding industrial wastes and storm-water), is more or less similar in composition in any community. This is because, in a specific geographic area, the daily activities, working, resting, rising up in the morning, washing and eating habits, are generally similar. Hence, the type and composition of sewage is usually constant in composition.

If we assume that normal flushing of W.C.s and normal washing of clothes, etc., are routinely carried out, the resulting domestic sewage is made up of about 99% water and 1% solids; some textbooks give the figures 99.9% water and 0.1% of other substances. The solid proportion includes microbial life, which may carry disease-causing organisms; floating solids, including oils and fats; settleable solids, which will sink eventually to the bottom of the water; colloidal solids, which are so small and light that they remain suspended in the water; soluble and insoluble material which respectively can or cannot be dissolved in the water, and which consists mainly of salts of various compounds, such as sodium salts (soluble) and calcium (insoluble), originating from foodstuffs; and other organic or inorganic compounds. The suspended solids, undissolved and hanging in the water, form the most important component of sewage, because they need the most treatment and are potentially the most dangerous to health, because of the microbial content. As we have seen in Chapter One, human excreta are the potential source of all gastrointestinal diseases, eggs of parasites, cysts of protozoa, pathogenic bacteria of typhoid and paratyphoid fevers, *Shigella* (source of bacillary dysenteries), etc.

Therefore, sewage and effluent should be looked upon as a possibly dangerous source of infection, since it is in part excreta. The fact that human excreta are mixed up with a large quantity of water should not deceive us. Actually, in sewage, the chance of spreading infective organisms is far greater than in a pit latrine or even from open-air defaecation: in the latter situations, infective organisms are limited to a fixed spot, whereas, in sewage, they are easily carried to any water source, better exposed to flies and other contaminative vectors, and can easily reach food, etc.

We need, therefore, to emphasize strongly that any sewage treatment and disposal method chosen should strictly meet the criteria set out earlier in this book for the proper disposal of human excreta.

5.3 THE DECOMPOSITION OF ORGANIC MATTER

Sewage or human excreta contain thousands and thousands of micro-organisms. Some of these originate from the intestinal tracts of man. Micro-organisms from this source may be divided into two categories. The first category, of immediate public health concern, includes the disease-causing organisms, commonly known as pathogenic organisms, or simply pathogens.

As we have seen earlier, these organisms may be helminths, protozoa, bacteria or viruses. These organisms are relatively much fewer in number, although they are the most important group.

The second largest group of micro-organisms found in human excreta are non-pathogenic. There are many types of these micro-organisms in human excreta, but the most numerous are the coliform group of organisms. These organisms are the natural inhabitants of the intestinal tracts of man and other animals. Generally, human excreta or sewage are full of these organisms, but, except in abnormal circumstances, these organisms are not harmful, either in animal intestines or in sewage.

In addition, all sorts of other micro-organisms get access to human excreta or sewage from the surrounding soil, water, air, animals and plants. These organisms are mainly responsible for the decomposition (putrefaction or fermentation) of human wastes or any other organic matter, into simpler compounds, after which the organic matter (wastes) becomes stabilized and does not change further.

Since sewage treatment depends on the process of decomposition, it is necessary to take a closer look at this process.

The process of decomposition

Micro-organisms are living things. Obviously, they need food (in solution form), and water (moisture); some need oxygen, and all need a favourable environment of suitable temperature and acid or alkali balance (pH).

From their method of respiration or energy-yielding metabolism, micro-organisms are divided into the following categories:

A. **Aerobic organisms**

The aerobic organisms (aerobes) grow and flourish in the presence of free oxygen, that is, involving the use of oxygen in the breakdown of organic or inorganic compounds.

B. **Anaerobic organisms**

Anaerobic ("not aerobic") organisms thrive only in the absence of free oxygen; they obtain their energy by the breakdown of substances not involving consumption of oxygen.

C. **Facultative organisms**

Facultative organisms live in the presence or absence of free oxygen, obtaining their energy accordingly

To summarize, all these organisms or bacteria involved in the treatment of sewage are non-pathogenic. But they are very important, because stabilization of organic matter is brought about as a result of their activities. They occur naturally in human wastes and other organic matter, and flourish when environmental factors such as food supply, temperature, moisture, pH, etc. are favourable. The process of decomposition takes place until the organic matter is transformed into material that can no longer support microbial life.

5.4. THE NITROGEN CYCLE

The process of decomposition of organic matter and the resulting phenomena in nature are generally illustrated by what is known as the *nitrogen cycle.*

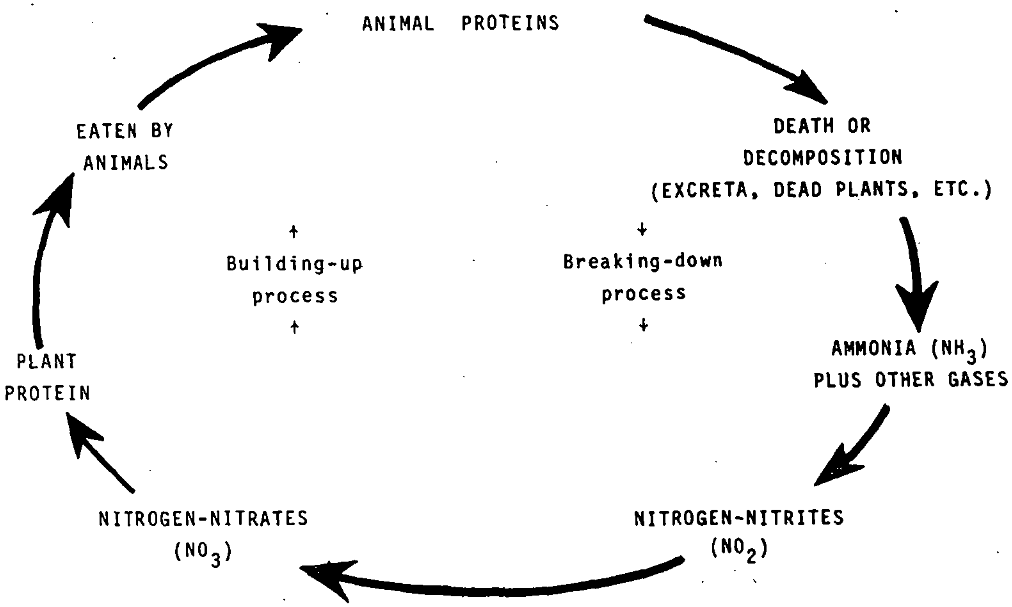
Among other things, proteins are major constituents of all living matter - animals and plants. Animal proteins contain complex molecules of nitrogen as an essential part of their composition. During the process of living or after death, the compounds of complex proteins are continuously broken down into more simple compounds. The breaking-down process is brought about in different stages by various groups of bacteria.

The stages of the breakdown are as follows:

The first stage of decomposition is marked by the production of ammonia (NH_3), hydrogen sulphide (H_2S), carbon dioxide, organic acids, etc.

Among these, the nitrogen-ammonia is converted into nitrites (NO_2) by a certain group of bacteria; the nitrogen-nitrites are further converted into nitrates (NO_3) by another group of bacteria. The nitrogen-nitrates, which are the end result of the cycle, are absorbed by plant roots to form vegetable proteins for plants. Plants (which are composed of proteins, carbohydrates, etc.) are eaten by man or animals to constitute their cell bodies. Thus, the cycle is repeated in nature (Figure 23).

FIGURE 23. The nitrogen cycle



Similar cycles also take place in nature for carbon and sulphur compounds, which are some of the other major ingredients making up animal or vegetable tissues.

It should be remembered that the nitrogen cycle takes place in any unstable organic matter: a dead body, decomposing human excreta or sewage, or a pile of organic wastes (garbage). Whether the process of decomposition will take place aerobically, or anaerobically, will depend upon the oxygen supply.

5.5. BIOCHEMICAL OXYGEN DEMAND (B.O.D.)

As described above, sewage is a complex unstable organic waste which has to be stabilized by the action of bacteria and other organisms. In other words, the offensive organic wastes (sewage) are converted into an inoffensive stabilized mass through the process of *oxidation*. Oxygen, therefore, is the single most important element necessary for stabilizing organic wastes. Consequently the strength of sewage is measured in terms of the amount of oxygen needed to stabilize the sewage. This amount of oxygen is known as the *biochemical oxygen demand* (B.O.D.). In technical terms, the B.O.D. is defined as the amount of oxygen required to bring about complete stabilization of a given strength of decomposable organic matter (sewage, in this case) by aerobic bacterial action.

In sewage, since the decomposable organic matter (the solid component of sewage) is relatively very small, the B.O.D. is expressed in terms of parts per million by weight (PPM) or milligrams per litre; B.O.D. is thus expressed in milligrams per litre or mg/l.

One of the main aims of sewage treatment is to reduce the B.O.D. of sewage to as low an amount as possible, in order to prevent anaerobic decomposition. When the B.O.D. of sewage is low enough, putrefaction or anaerobic decomposition (characterized by unpleasant and offensive smells) will not take place.

5.6. DISSOLVED OXYGEN (D.O.)

Whether intentionally or unintentionally, sewage may get access to a water-course. It is not uncommon to see raw sewage or effluent being deliberately discharged into rivers, streams, lakes or the ocean; or unintentionally, gravity carries fluid to the level of water. What happens to a body of water which receives raw sewage or partially treated sewage?

We have said that sewage is unstable organic matter that has to be stabilized by the process of oxidation through the activities of aerobic or anaerobic bacteria. We have learned that aerobic bacteria function in the presence of free available oxygen, while anaerobic bacteria function only in the absence of free oxygen.

When water comes in contact with air, it becomes saturated with oxygen. This oxygen is termed *dissolved oxygen* (D.O.). Accordingly, all natural (unpolluted) waters contain dissolved oxygen. The actual amount of dissolved oxygen present in water at a given time and place will depend upon the temperature of the water, and on the pressure of oxygen in the air.

Under normal temperature and pressure, all natural waters contain a maximum concentration of D.O. This amount usually varies from 8 to 12 PPM (parts per million per weight), which may be considered as 100% concentration of D.O. in water. Fish and other aquatic life depend for their oxygen supply, and thus their existence, on this dissolved oxygen.

When sewage or other organic wastes are discharged into a watercourse, the D.O. is reduced. Fish and other aquatic organisms, and also aerobic bacteria which depend on the D.O., will gradually diminish in number because of the scarcity of free oxygen. If the condition does not improve, anaerobic decomposition will take place. Under such conditions fish and other aerobic organisms will gradually die off. Most fish species will live only when the minimum concentration of D.O. is above 50%.

The depletion of D.O. from water can entirely upset the ecological balance of the aquatic life. However, if the volume of sewage or organic waste discharged is limited or relatively low in B.O.D., the receiving body of water (the stream, river or lake) will regain its concentration of D.O. through physical, chemical and biological processes, such as sedimentation, aeration, sunlight, diffusion, etc.

Therefore, the main aim of sewage treatment is to prevent the occurrence of anaerobic conditions in the receiving body of water, and prevent contamination of any water source by pathogenic organisms which may be present in the sewage or effluent. It is therefore important to be aware of some of the typical treatment and disposal methods of sewage.

CHAPTER SIX

INDIVIDUAL SEWAGE DISPOSAL SYSTEMS

By the term "individual sewage", we mean the water-borne excreta or wastes originating from normal living processes, from residences and from institutions such as schools, hospitals, restaurants, hotels, etc.

An individual sewage disposal system, like any other excreta disposal system, must satisfy the criteria set out in Chapter One for the safe disposal of human wastes.

There is no single individual sewage disposal method that can be universally applied under all conditions. However, the selection of a particular method will depend upon the following major factors:

1. The quantity of sewage to be disposed of
2. The degree of sewage treatment to be achieved
3. The nature of soil formation and stability of the locality
4. The presence of ground-water, and whether it is used as the source of the water supply
5. The level of the water table of wells or other sources of water, and the hydraulic gradient (the downward slant of direction of flow) of the water
6. The proximity of the disposal site to surface water sources
7. The availability of adequate land for sewage disposal
8. The relative cost of the method of disposal (capital operation and maintenance).

Bearing in mind the above major determinants, we shall now examine some of the typical methods in practice for individual sewage disposal.

6.1 DISPOSAL BY DILUTION

Although unsanitary, it is a common practice in some areas to discharge raw sewage or effluent into nearby bodies of water such as streams, rivers, lakes, etc., so that it is diluted or reduced in strength by the water.

The reason for this practice was based on the false idea that the receiving bodies of water assimilated the sewage or effluent through the process of "self-purification of streams" - that the water cleansed itself and re-established its natural status.

Self-purification of streams does in fact take place in nature, but there are several important factors needed for this phenomenon to be successful, for example, (a) the volume of the receiving body of water in proportion to the volume of sewage or effluent discharged, and (b) the depth and rate of flow of the receiving body of the water.

On the whole, the capability of a receiving body of water to regain its dissolved oxygen, after the incoming sewage or effluent has been efficiently stabilized, governs the success of this system of disposal.

In earlier times, it was believed that, if the receiving body of water was 20 to 40 times as much as the sewage to be discharged, self-purification was certain. Now, however, we know that, although, in nature, physical, chemical and biological forces, such as sedimentation, sunlight, reaeration, photosynthesis, temperature and other factors, all help the success of self-purification, the interplay of the factors are too complicated to rely upon to stabilize sewage without creating a nuisance or health hazards.

If a relatively *very small* volume of sewage or effluent (with *very low* B.O.D.) is diluted with a large body of water in nature, stabilization of the sewage takes place, and the body of water regains its original status. But if the incoming sewage is more than the natural water can cope with, the D.O. gradually diminishes. Fish and other aquatic life start to die off, and the ecological balance in the receiving body of water is completely disturbed. Under such conditions, anaerobic decomposition takes place, creating offensive conditions. The colour of the water becomes black and muddy, and it smells. Moreover, the likelihood of the spread of infectious organisms greatly increases.

Therefore, the disposal of raw sewage or effluent should never be carried out unless under strict rules and the regular supervision of the Public Health Department of the locality concerned.

The method described above is included in this book only to indicate that it is one of the dangerous methods of sewage disposal, which, wherever it has been extensively used (also in developed countries), causes a hazard to health that takes many decades to overcome.

6.2. THE LEACHING TYPE OF CESSPOOL

The leaching type of cesspool is a pit dug in the ground in order to receive raw sewage, from which the liquid portion seeps or leaches off into the surrounding soil, while the solid component (sludge) is retained in the pit. The depth of the pit will depend upon the nature of the soil formation, particularly its capacity for allowing the liquid portion of the sewage to percolate or filter through it. Generally a diameter of 90 to 120 cms and a depth of 2 to 3 metres will give a reasonable capacity, provided the soil is adequately porous, and can let the liquids drain off.

The side walls of the pit are constructed with open joints in order to facilitate seepage of the liquid portion, while the topmost part (60-90 cms) is plastered, to make it watertight. A concrete slab cover with a man-hole is provided to permit access to the pit, and an outlet pipe takes the effluent into another pit or series of pits (Figure 24).

In the cesspool, the solid portion of the sewage settles down in the bottom and undergoes anaerobic decomposition, while the liquid portion seeps off into the surrounding porous soil. Percolation of the liquid portion takes place through the open-jointed sides and the bottom of the pit. The rate of percolation will depend mainly upon the porosity of the soil layer. Porosity of the soil is determined by a *percolation test*, which will be dealt with later on.

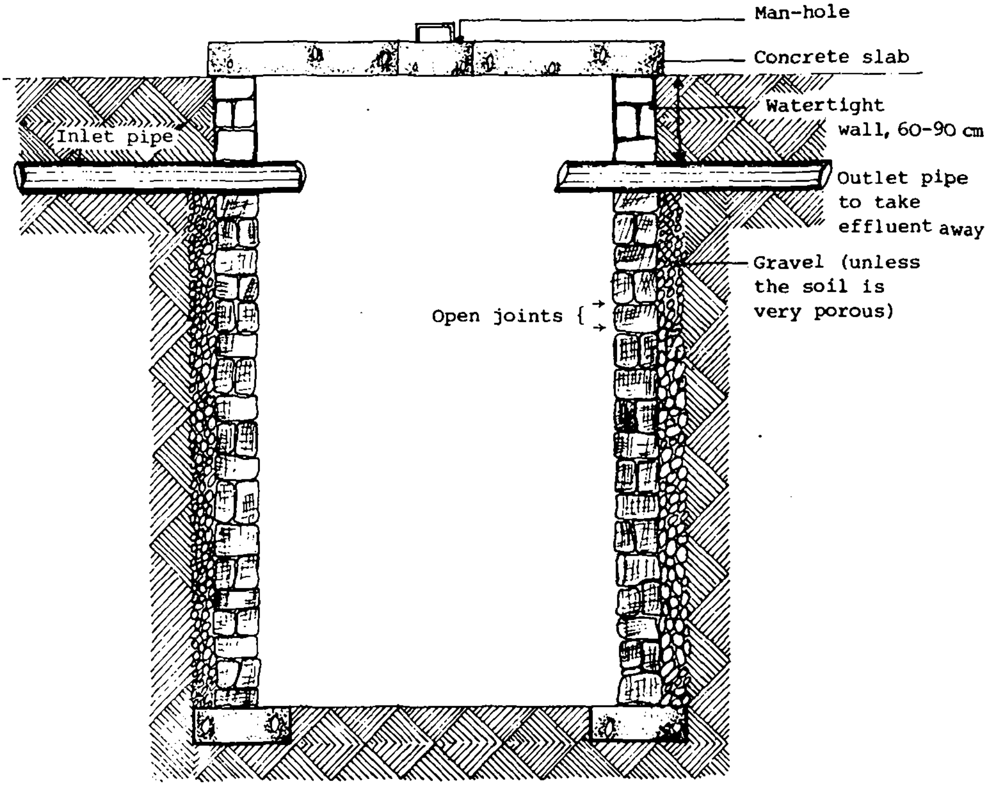
Leaching cesspools do not usually require emptying. However, after a long period, the pores of the soil in contact with the sewage become clogged or blocked, thus hindering the percolation process. In these circumstances, the sewage will overflow onto the surrounding earth surface. As a result, darkish-coloured stagnant pools are formed, creating favourable conditions for water source contamination, fly-breeding and nuisances such as objectionable odours.

Public Health experts do not recommend the leaching type of cesspool except in very special circumstances. For example, it can be used for small families in localities where the soil formation is sufficiently porous; where wells or springs are properly protected; or where surface water is adequately hygienically treated.

If the conditions of a locality dictate the use of the leaching type of cesspools, then the cesspools should be sited at least 30 metres away from and on a lower level than wells or other sources of drinking-water. The height of the ground-water table should be at least 1.20 metres below the bottom of the cesspool, so that, by allowing any sewage waters that might reach the ground water to be filtered through the earth and thus cleaned, contamination of the ground water is avoided.

In order to avoid overflow of sewage onto surrounding surfaces, two or more cesspools should be constructed and connected, to receive the effluent and allow it to seep away.

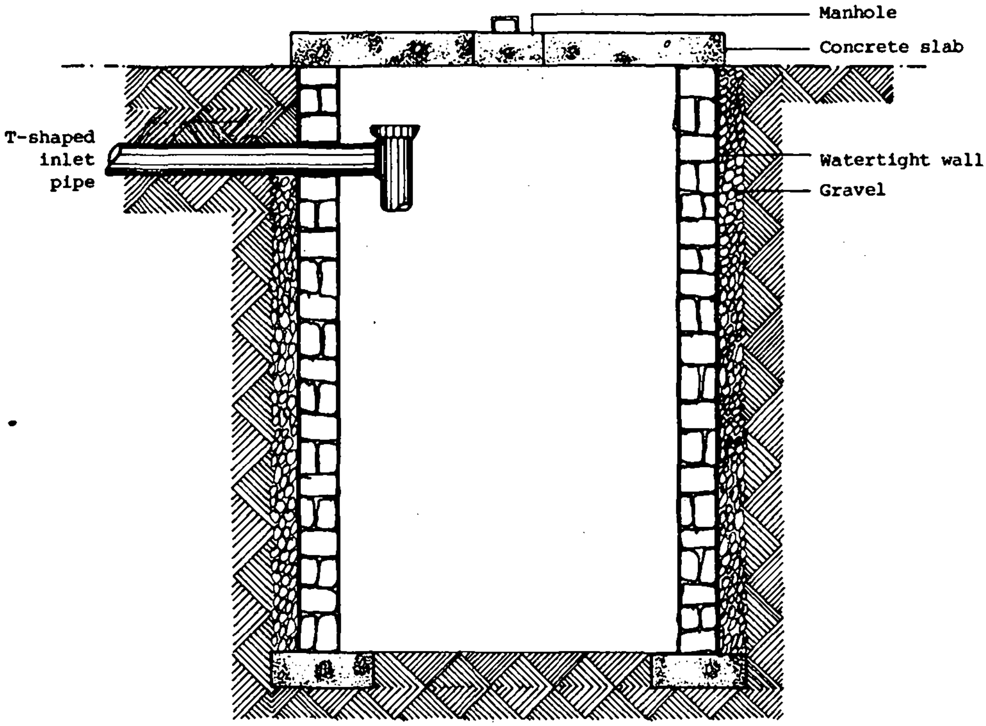
FIGURE 24. Leaching or open-joint type of cesspool



6.3. THE WATERTIGHT CESSPOOL

Watertight or impermeable cesspools are similar to the leaching type of cesspool, except that, as the name implies, they are made waterproof in order to receive and store raw sewage (Figure 25). The sides as well as the bottom of the pit are made watertight. A tightly-fitting

FIGURE 25. Watertight cesspool



slab cover with a man-hole in the centre is placed over the top to prevent the escape of foul gas and to permit emptying the pit when full. The man-hole is usually 60 cm by 60 cm, just big enough for a man to inspect the flow of sewage. Raw sewage is led into the tank through a sanitary T-shaped pipe or inlet pipe. Inside the watertight tank, the sewage undergoes anaerobic decomposition, but this should not be considered sewage treatment.

When the tank is full, the contents are bailed out (removed by pails or other means) and taken to the final disposal site. Usually the periodic emptying is carried out by a specially designed lorry or truck which has a suction pump; the pump sucks out the sewage from the tank, and the sewage is carried in the lorry's sealed body to a final disposal place. The time interval for emptying will depend upon the volume of the sewage, which in turn depends on the number of users. The tank can be designed in such a way that emptying can take place at an interval of one year or six months. Regarding the required capacity of the cesspool, Wagner and Lanoix give the figures of 68 litres per person per month, or 408 litres per person when emptying is done every six months.

The main problem of the watertight cesspool lies in the periodic emptying and disposal of the contents. During the process of emptying, the likelihood of contaminating surface soil and water sources, and accessibility to flies, is great. The final disposal of the contents, which are almost entirely raw sewage, is generally done by dumping it on low-lying land or by burying it in properly constructed trenches. The former method should be avoided as far as possible, because the possibility of spreading disease-carrying organisms and creating a nuisance is very great. But, if this is the best alternative, the sewage should be properly covered with 60 cm to 90 cm of dry earth, sawdust or similar material, in order to prevent accessibility to flies and other vectors of disease.

In areas where composting of human wastes is practised, the contents of the watertight cesspool can be transformed into fertilizer. Thus the end result is proper excreta disposal as well as obtaining valuable fertilizer.

6.4 THE SEPTIC TANK SYSTEM

A septic tank is a watertight container into which raw sewage is discharged and retained therein for a predetermined period, during which the sewage gets partial treatment.

The septic tank system of sewage disposal has been in use for the past 100 years. Numerous studies have been made on its function and design, as a result of which it has become the standardized method for the treatment and disposal of sewage for individual households in semi-urban and rural areas, and for institutions such as schools, hotels, hospitals, etc.

Sewage treatment and disposal by a septic tank system takes place in two stages:

A. The first stage takes place in the septic tank itself, where the incoming raw sewage is decomposed by the action of anaerobic bacteria and fungi; hence the term "septic" is applied to the tank.
B. The second stage of treatment takes place outside the septic tank, by the action of aerobic bacteria and other organisms.

After the digestion of the raw sewage, the liquid portion which comes out through the outlet pipe is called effluent. No matter how efficiently the septic tank functions, the effluent should never be considered treated or safe for discharging into a body of water. The treatment of effluent is carried out under aerobic conditions, as will be described later. But a septic tank that does not have adequate disposal of the effluent is merely a holding tank, and fails to fulfil its purpose.

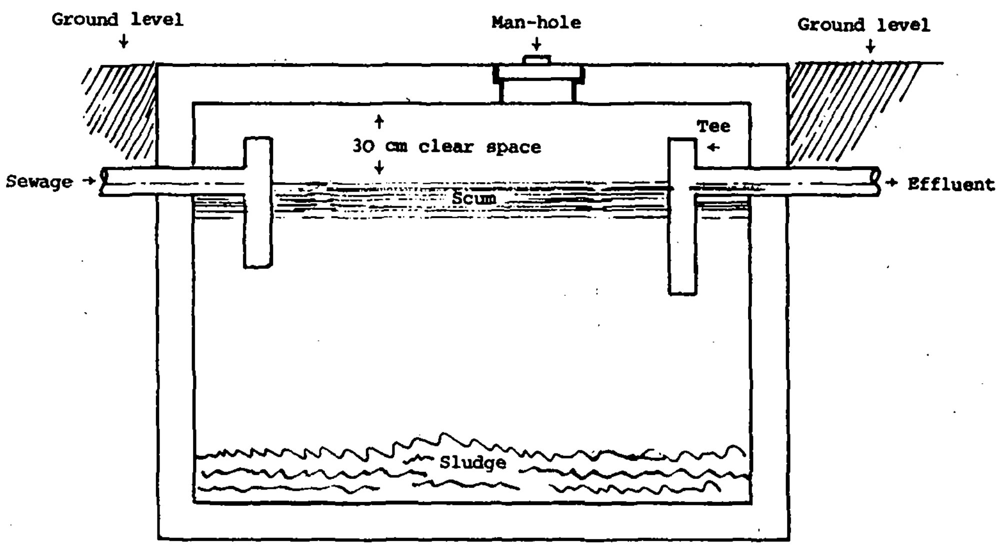
Primary treatment

The raw sewage which enters the septic tank through the inlet pipe is left quiescent in the tank for a predetermined period, usually one to three days. During this period (called "the retention period"), the solid component of the sewage settles down in the bottom of the tank, while light floating solids collect together and form a floating or partially submerged mat on the surface of the liquid. This floating mat is called scum. Thus the incoming sewage forms three layers in the septic tank, the scum on the surface, the liquid portion in the middle, and the heavy settled solids or sludge at the bottom of the tank.

The sludge stored at the bottom and the lower part of the scum on the surface undergo decomposition by the action of anaerobic bacteria and fungi. As a result of this process the volume of the solid portion of sewage is drastically reduced. The liquid portion, the effluent, after the proper retention period, is discharged through the outlet pipe and is led to a final disposal site (Figure 26).

FIGURE 26. Cross-section of a typical household septic tank

(Scale 1 : 20)



The quality of the primary treatment depends upon several factors, the main ones being the capacity and proper design of the tank, the retention period, and the abundance and efficient functioning of the anaerobic bacteria.

The capacity of a septic tank

The capacity and the relationship of the dimensions (length, width and depth) of the septic tank are the most important determinants for efficient functioning. Based on many years of studies and experiments, the size, shape and the design criteria of the septic tank have been more or less standardized. However, the design criteria described here should be adapted to local conditions as need arises.

The size of a septic tank is very important from the economic point of view as well as for the satisfactory functioning of the tank. The capacity of the tank is governed by three main factors:

1. The average daily flow of sewage to be treated
2. The retention period of the sewage in the tank
3. Adequate sludge storage, for desludging once at intervals of two to four years.

The average daily flow of sewage to be treated will depend upon the number of users and the daily water consumption of a locality. The daily water consumption per capita is influenced by the availability of piped water in the home, the cost, and the washing habits of the people in a community. Water requirements per capita per day vary from country to country, and with the standards of living even within the same community. In the U.S.A., where a great deal of research has been done on septic tanks, the daily minimum requirement of water is reckoned to be 50 gallons (190 litres) per capita for dwellings. In actual fact, roughly 80% of the water used per capita goes to sewage. Hence, it is safe to assume that the daily water consumption per capita is approximately equivalent to the daily sewage contribution per capita. Septic tanks are designed in developed countries, especially in the U.S.A. (familiar to the writer), on the basis of 50 gallons (190 litres) per capita per day. Accordingly, the minimum size of a septic tank is calculated as 500 gallons or about 2000 litres. Then allowance is made per number of users at an average rate of about 2.25 cubic feet. The capacity and dimensions indicated in Table 11 are based on this assumption.

In many developing countries the daily per capita water consumption is much less than 50 gallons (190 litres). Experience indicates that the daily water consumption per capita is at most about 100 litres in urban areas, and about 45 litres in rural areas. Reckoned on this basis, the capacity of the septic tank might be much smaller. However, it is advantageous to have a large capacity tank; hence it is advisable to maintain the already established design criteria, as the large size will increase the periods between desludgings during the operation of the septic tank.

The retention period

Generally, the longer the incoming sewage is kept quiescent in the septic tank, the easier it is for the anaerobic bacteria to digest the sewage. In practice, however, the retention periods vary from 24 hours to three days. Therefore, the capacity of the septic tank should be enough to hold the daily flow of sewage for the above period.

Another factor is the capacity of the tank to store sludge for a reasonable period. The sludge accumulated in the bottom of the tank is continually reduced in volume to about 60% or less, due to its decomposition by the anaerobic bacteria. Yet, after long use, the accumulation of sludge reaches a point where it interferes with the proper functioning of the septic tank. At this point, the accumulated sludge has to be bailed out and the tank is desludged. The intervals between desludging are usually two to four years or longer.

In summary, the daily flow of sewage, the retention period and the desludging interval govern the capacity of the septic tank to be constructed (Tables 11 and 12).

TABLE 11. Required capacities* for septic tanks serving individual dwellings

Maximum number of persons served	Nominal liquid capacity of tank (US gallon)	RECOMMENDED				DIMENSIONS			
		Width		Length		Liquid depth		Total depth	
		feet	inches	feet	inches	feet	inches	feet	inches
4	500	3	0	6	0	4	0	5	0
6	600	3	0	7	0	4	0	5	0
8	750	3	6	7	6	4	0	5	0
10	900	3	6	8	6	4	6	5	6
12	1100	4	0	8	6	4	6	5	6
14	1300	4	0	10	0	4	6	5	6
16	1500	4	6	10	0	4	6	5	6

Reproduced from *Excreta Disposal for Rural Areas and Small Communities*, WHO (1958), Monograph No. 39.

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

N.B. 1 US gallon = 3.75 litres
1 inch = 2.5 cm
12 inches = 1 foot

TABLE 12. Required capacities for septic tanks serving camps and day-schools

Maximum number of persons served		Nominal liquid capacity of tank (US gallon)	RECOMMENDED DIMENSIONS							
			Width		Length		Liquid depth		Total depth	
Camps	Day-schools		feet	inches	feet	inches	feet	inches	feet	inches
40	60	1000	4	0	8	6	4	0	5	0
80	120	2000	5	0	11	0	5	0	6	3
120	180	3000	6	0	13	6	5	0	6	3
160	240	4000	6	0	18	0	5	0	6	3
200	300	5000	7	6	18	0	5	0	6	6
240	360	6000	8	0	20	0	5	0	6	6
280	420	7000	8	6	20	0	5	6	7	0
320	480	8000	8	6	23	0	5	6	7	0

Reproduced from *Excreta Disposal for Rural Areas and Small Communities*, WHO (1958), Monograph No. 39.

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.

The design of a septic tank

As forms of septic tank have been in use for many years, the design has been fairly well standardized.

Although a septic tank can be designed in any shape, experience has revealed that the best shape is rectangular. The most commonly used dimensions for a rectangular septic tank are as follows:

The length should not normally be less than twice nor more than three times the breadth. The total liquid depth, including sludge storage space and space for scum, is generally not more than 180 centimetres, and is more often 120 cm to 150 cm. A clear space of 30 cm is maintained above the liquid level of the tank for gases resulting from anaerobic decomposition. The inlet and outlet pipes are usually "T"-shaped, and are called "tees". This shape helps to prevent gas from escaping, and is therefore also known as a baffle. Both inlet and outlet pipes should be installed 20 to 30 cms from the side-walls of the tank, and the outlet tee or baffle should descend about 5 cms deeper into the liquid (Figure 26). The tank is constructed from reinforced concrete; the thickness of the wall is usually around 15 cm. The top of the tank is fitted with a concrete cover with a manhole for the purposes of inspection.

The septic tank shown in Figure 26 has a total liquid capacity of 3,036 litres, and it is assumed to be adequate for a family of 8 to 12 persons, with a desludging interval of 4 to 6 years. Table 11 gives the relative capacity for camps and day-schools on the basis of 95 litres and 64 litres per person per day respectively.

Septic tanks meant to serve a large number of people are usually designed in two compartments or chambers. In such circumstances, the first compartment of the tank is usually designed to hold two-thirds of the total volume (Figure 27a and b).

FIGURE 27. A typical design of a double-compartment septic tank

(a) PLAN

(Figures in centimetres)

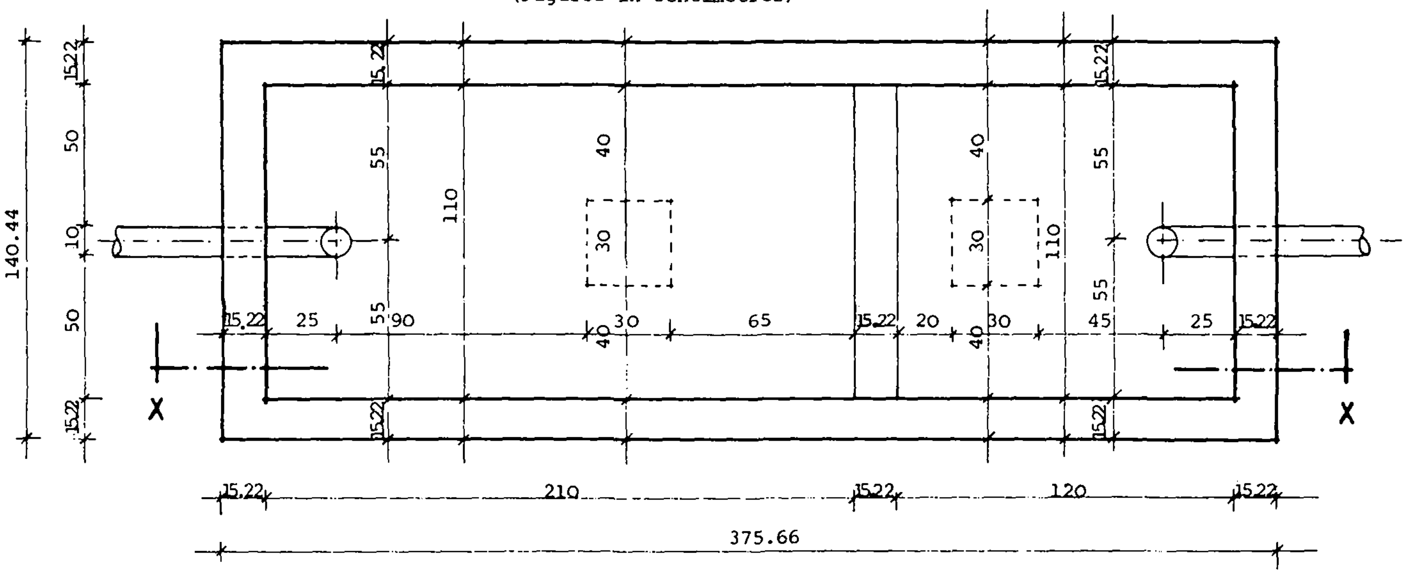
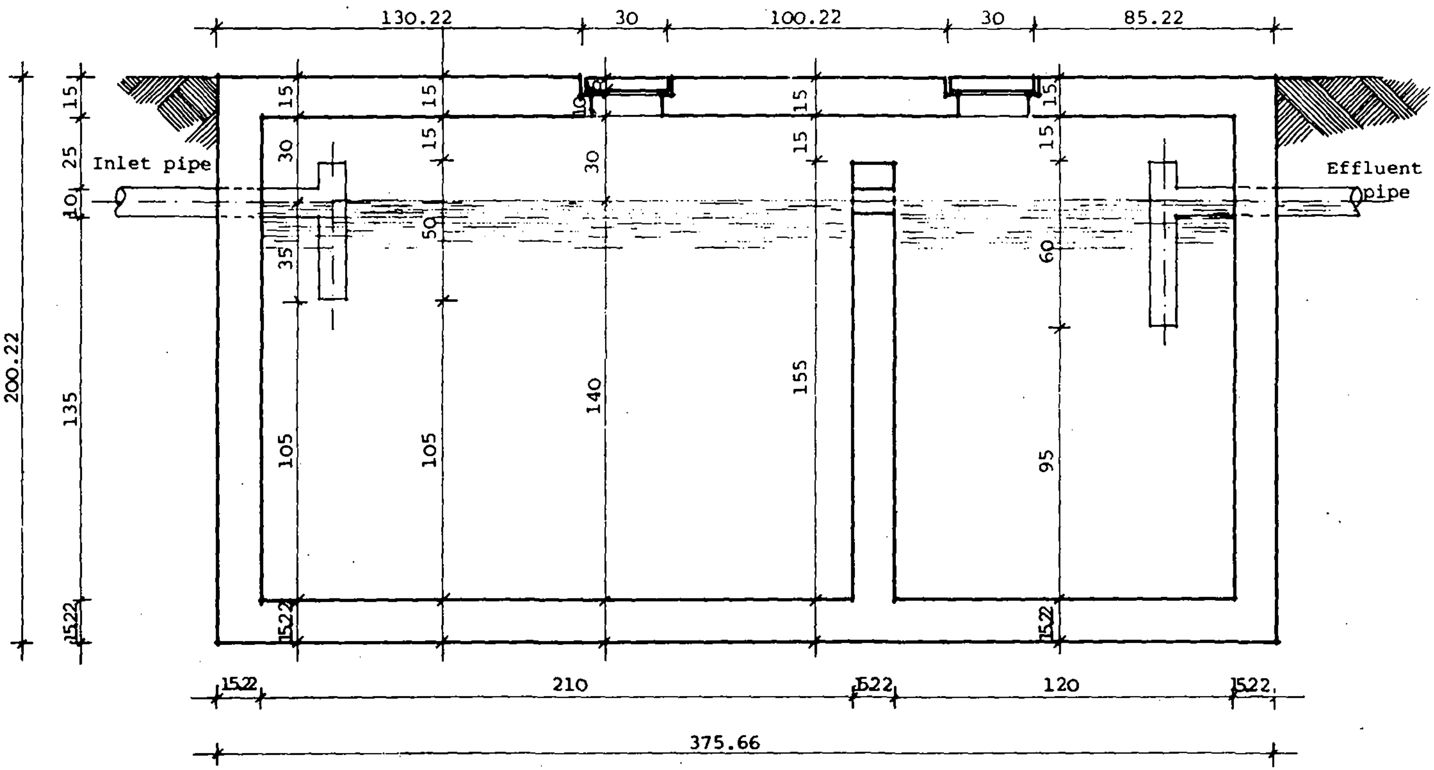


FIGURE 27, continued. A typical design of a double-compartment septic tank

(b) SECTION X - X, as shown in Figure 27(a)

(Figures in centimetres)



The above design specifications provide general guidelines, subject to adaptation to specific situations.

Location

A septic tank should be located a minimum of 2 metres from any property line or boundary, at least 3 metres from any dwelling-place, and 20 metres from any water source. If possible, it should be on ground lower than a source such as a well. Preferably, it should be constructed on the same level as the ground surface, and, if it has to be below ground-level, it should not be more than 30 to 45 cms below the ground, so that maintenance workers can easily see into it.

Operation and maintenance of the septic tank

The proper and efficient functioning of the septic tank depends on the routine, regular maintenance of the tank. Since the primary treatment of sewage in the septic tank is brought about by anaerobic bacteria and fungi, it is important to create and maintain a favourable environmental situation for them to multiply and flourish.

Newly constructed septic tanks should therefore be "seeded" or "planted" with anaerobic bacteria and fungi, by pouring into the new tank about two buckets of sludge from an old septic tank which has been operating for a long time. (This is somewhat like using a portion of old *injera* or sour dough when new bread is prepared; it starts fermentation). In this way, the operation of the new tank is speeded up.

The addition of any form of disinfectant into the drainage system or the septic tank should be discouraged, as the disinfectant would interfere with the proper functioning of the anaerobic bacteria.

A timetable should be set for desludging the septic tank at regular intervals, say every two to four years. Advice should be asked from the local Health Authority about the construction, operation and maintenance of the septic tank.

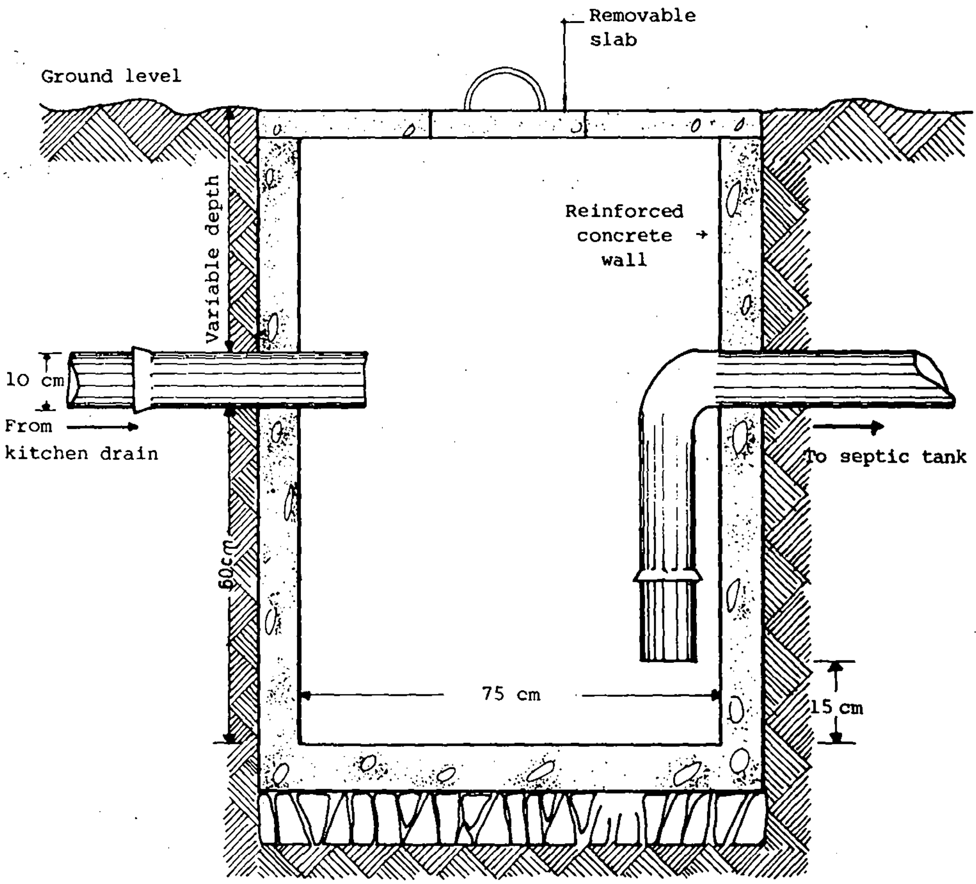
The grease-interceptor

Waste-water from domestic kitchens, W.C.s, bathrooms, etc., can be discharged into the septic tank. However, waste-waters from large kitchens, in institutions such as schools, hotels, restaurants, and hospitals, are likely to contain a lot of oily, fatty, greasy substances which would interfere with the proper functioning of the septic tank, by blocking the absorbing capacity of the soil when they drain into a soakage pit. Waste-waters from large kitchens are therefore allowed to flow into a grease-interceptor or grease-trap before discharging into the septic tank or seepage pit (Figure 28). The grease-trap should be large enough to allow the incoming waste-water to be held in it until the grease cools and floats; that is, the size of the grease-interceptor should hold about five times the volume of waste-water that is likely to be discharged into it at any one time. When the grease is floating, it is removed from the top of the trap into buckets, etc., and disposed of by burying in a trench.

Before concluding this section on septic tanks, it should be remembered that the design and construction of septic tanks as well as of other individual sewage disposal methods should be approved by the local Health Authority or a similar agency appointed to control health and safety hazards. These authorities should have a code of regulations regarding the minimum standards governing the design, construction, operation and maintenance of whatever system is chosen.

On the whole, however, the septic tank system is relatively expensive, difficult to maintain and not really suitable for the needs of a growing town or city, since the eventual disposal of the sewage and effluent requires plenty of open space. Nevertheless, a city like

FIGURE 28. A grease-interceptor for hospital or school kitchens

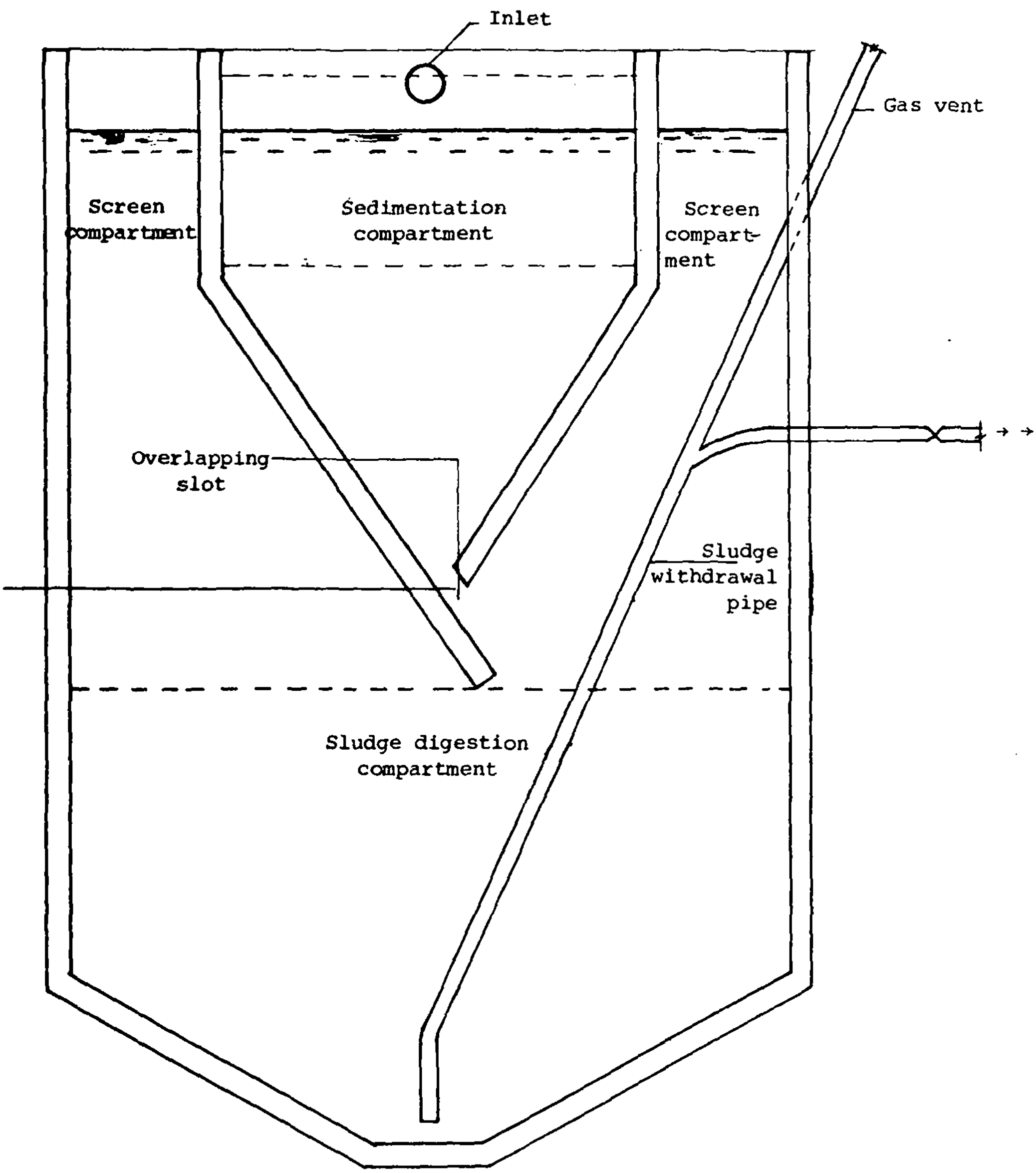


Addis Ababa uses the septic tank system for large residences in many areas, and may have to continue to do so until other methods of sewage disposal are available.

6.5. THE IMHOFF TANK

The Imhoff tank, named after its inventor, Karl Imhoff of Germany, is a modification of a septic tank, used for large individual sites such as factories. As in the septic tank, the anaerobic decomposition of sewage takes place in the same tank but in a separate compartment from that where sedimentation takes place. Hence, an Imhoff tank has two separate compartments in one tank (Figure 29).

FIGURE 29. Cross-section of an Imhoff tank



Sewage is allowed to flow into the sedimentation compartment or upper storey, which has sloping bottom walls, bent at an angle towards each other. At the lowest point of the sedimentation compartment, there is a slot left open between the sloping walls through which the settled solids (sludge) fall at a very low velocity (less than 30 cm per minute) into the sludge digestion compartment. One of the sloping walls of the upper compartment is made to overlap at the slot and descends about 45 cms deeper into the lower compartment. The purpose of this is to stop the gases formed in the lower compartment from going into the upper compartment.

Normally the retention period of the sedimentation compartment is 2 to 3 hours. The sludge accumulated in the lower compartment is digested by anaerobic bacteria. The digested sludge is drawn off by gravity at intervals of about 45 days through the sludge-withdrawal pipe, and is disposed of as described for other systems.

The sludge-withdrawal pipe usually has a diameter of 20 cms minimum, and descends to about 30 cms above the bottom of the lower compartment. The bottom walls of the lower compartment are also designed to slope inwards, in order to facilitate the withdrawal of the digested sludge, which is concentrated at the lowest part. Gases generated as result of decomposition escape directly through the branching top end of the sludge-withdrawal pipe; this branch is called a gas vent (Figure 29).

Depending on the design, the digested sludge can be also withdrawn by pumping.

While the Imhoff tank is more efficient than a normal septic tank, it is quite expensive to construct, and moreover needs constant skilled supervision. Consequently its wide use in developing countries like Ethiopia is limited in the foreseeable future.

CHAPTER SEVEN

TREATMENT AND DISPOSAL OF EFFLUENT

7.1. PRIMARY TREATMENT: SEWAGE

As stated earlier, in a well-designed and well-constructed septic tank, the raw sewage is digested by anaerobic organisms, and as a result the suspended solids are greatly reduced. (See also Chapter 5.) Consequently, the effluent discharged through the outlet pipe has a greatly reduced biochemical oxygen demand (B.O.D.). However, the reduction that has occurred is incomplete, and further treatment is needed. More important than the B.O.D. is the bacteriological status of the effluent. Studies made in many parts of the world show that pathogenic organisms such as the eggs and cysts of parasites, and bacterial and viral organisms, are still capable of passing unharmed to the effluent while the sewage is being digested in the septic tank.

Therefore, for all practical purposes, the effluent should be considered as potentially dangerous as the raw sewage.

7.2. SECONDARY TREATMENT: EFFLUENT

Unlike the primary treatment in the septic tank, which is caused by anaerobic bacteria, the treatment of the effluent is brought about by the action of aerobic bacteria. That is to say, aerobic bacteria oxidize the organic matter which is degradable or can be digested in the effluent; the end result is stabilization. Since aerobic bacteria multiply and flourish in the presence of free oxygen, they are normally found in abundant numbers in the upper layers of the soil, sand or beds of stone, where natural aeration continues uninterrupted. The best or optimum level for their growth and multiplication is usually the upper 60 cms of the soil layers.

7.3. FACTORS INFLUENCING THE TREATMENT AND DISPOSAL OF EFFLUENT

In many instances, failure of the septic tank system is due mainly to inadequate provision for the treatment and disposal of effluent. We must emphasize that, before concentrating on the design and construction of a septic tank, it is essential to settle the problem of safe effluent disposal.

Technically there are several methods for the treatment and disposal of effluent. However, the selection of the most appropriate methods for a given locality depends upon the following factors:

1. The nature of the soil formation - in particular, its capacity to absorb the effluent produced
2. The proximity of wells and other water sources
3. The depth of the ground-water table
4. The availability of adequate space
5. The cost.

Once these factors are taken into consideration, a choice can be made from among the methods described below.

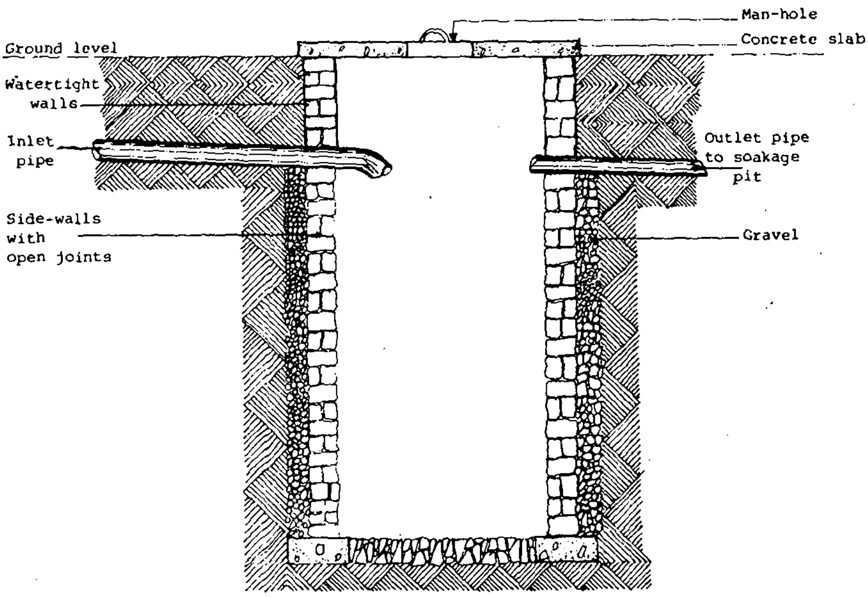
7.4. THE SEEPAGE PIT

The seepage pit, otherwise known as a soakage pit or absorption pit, is a pit dug in the ground to receive effluent from a septic tank, and to allow the effluent to seep, leach, or percolate into the ground.

Like the leaching type of cesspool (Chapter Six), the seepage pit is also used to dispose of effluents from cesspools, aqua privies, waste-water from kitchens, etc.

The side-walls and the bottom of the seepage pit are constructed with open joints, unsealed, in order to facilitate percolation (Figure 30).

FIGURE 30. A seepage pit



A series of seepage pits (and also of leaching cesspools) can be constructed connected one to another, to dispose of the volume of effluent produced.

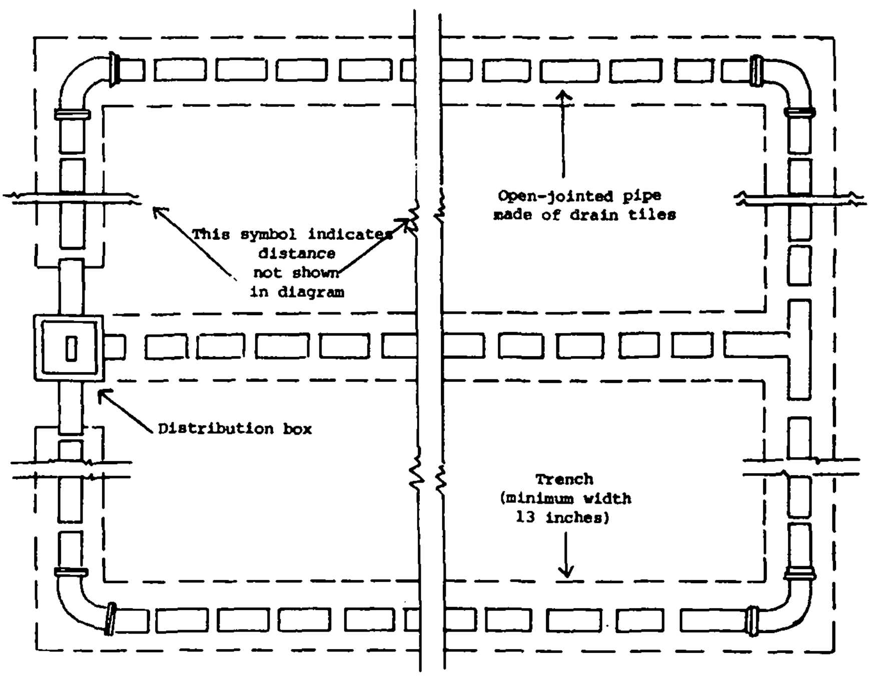
The seepage pit system can be used only to dispose of effluent from individual houses in places where the absorption capacity of the soil is satisfactory, where adequate space is available and where wells are not used as the source of water supply.

7.5. THE SUB-SURFACE ABSORPTION SYSTEM

In the sub-surface absorption system (sometimes called the sub-surface irrigation system), the effluent from a septic tank is led to a disposal field, where it is discharged into the top layers of the ground by means of open-jointed drain tiles, more accurately called open-jointed concrete pipes. These large-sized concrete pipes are made with perforations or holes in them, and they are laid in trenches dug at a depth of about 30 to 60 cm below the surface of the ground. The effluent discharged through the open joints is digested by the aerobic bacteria present in the top layers of the soil, and the resulting liquid percolates or seeps away into the surrounding ground (Figure 31).

FIGURE 31. A sub-surface absorption trench disposal system

(Scale 1 : 20)



Generally, from two to four surface irrigation tiles or pipes are laid at the sides of the main drain or sewer leading from the septic tank, and these pipes are therefore called laterals. Their number depends on the volume of effluent to be treated. The effluent is uniformly and equally dispersed into each line of drain tiles by means of a distribution box designed for this task (Figure 31).

The length of each drain tile or pipe is usually 30 metres, and the distance between the pipes is about 3 metres. The drain tiles are laid in a trench, leaving about 1.25 cms of open joints at regular intervals, in order to allow the effluent to leach into the ground. The upper half of the open spaces is covered with straw, fibre, coarse gravel or strips of tar paper, in order to prevent the spaces being clogged with soil when the trench is covered.

The choice of the sub-surface irrigation system, and its success, depends on the ability and capacity of the soil to absorb the volume of effluent to be disposed of. The absorption capacity of soil varies from place to place, in accordance with the type of soil formation, and this must be found out before deciding to install a sub-surface irrigation system.

Percolation test

The absorption capacity of soil formation is usually determined by a test called a *percolation test*. This test is carried out by digging a series of holes with a radius of 30 cm, and depth of not more than 60 cm, uniformly or equally spaced, in the proposed disposal field. These holes, usually six or more, are carefully scratched on their sides and bottoms to make the surface rough, so that soil particles likely to cause a smeared, smooth surface that would hinder percolation do not cling to them. Loose earth resulting from digging is also completely removed. Then fine gravel or coarse sand is placed at the bottom of the hole to a depth of about 5 cm to facilitate natural percolation. Each hole is filled with clear water up to a height of 30 cm. The time required for the water to percolate away is carefully recorded in minutes. This procedure is repeated until results showing a constant time of percolation rate are obtained for the whole of the proposed disposal field.

Obviously, the less time it takes for the water to percolate away, the better is the absorption capacity of the soil. The relationship between the percolation time and the absorption capacity rate has been tabulated for different types of soil formation, on the basis of many years of experience. The result of a percolation test of a specific locality can be compared with others by consulting Table 12, and a decision can be made whether the sub-surface irrigation system can be used. For further details, the reader is advised to consult some of the references listed at the end of this text.

As a general guideline, it should be noted that neither the sub-surface irrigation system nor the seepage pit can be used in the following areas:

1. Where there is no adequate space for the volume of effluent produced;
2. Where the absorption capacity of the soil formation is unsatisfactory;
3. Where the water table is high, that is, nearer to the surface of the ground;
4. Where shallow wells are used as a source of water supply.

7.6. OXIDATION PONDS FOR TREATMENT OF EFFLUENT

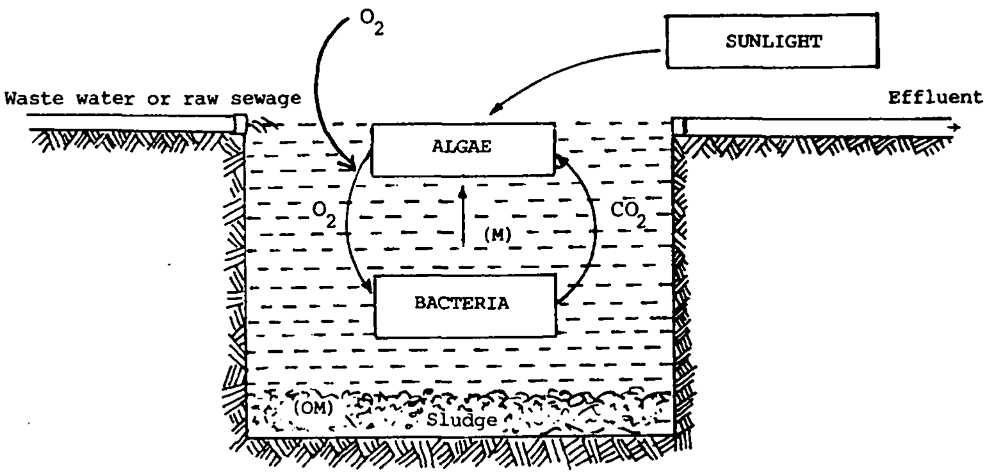
Oxidation ponds, perhaps better known as waste-stabilization ponds, are large, shallow man-made ponds or pools designed and constructed to receive and retain raw sewage or effluent for a fixed period, but in this chapter they are discussed only in relation to effluent. During this period, digestion of the organic components of the waste-water is brought about by aerobic bacteria and algae. The oxidation pond, if properly designed, constructed and operated, is one of the cheapest and most effective methods for complete treatment of sewage in hot or tropical countries, especially in developing countries like Ethiopia, but this will be considered in the next chapter.

The activities that take place in oxidation ponds are very complex, involving natural biological, chemical and physical processes. However, two major factors are largely responsible for the stabilization of organic wastes. They are *aerobic bacteria* and *algae.*

As we have learned, aerobic bacteria digest and oxidize the organic component of the sewage or effluent. Algae, present in the ponds, manufacture their foods with the help of sunshine (solar energy), using carbon, carbon dioxide, ammonia and other raw materials resulting from bacterial action. This process is called *photosynthesis.* The end result of photosynthesis is the production of nutrients for algae cells and the release of free oxygen, which is needed by aerobic bacteria for their growth and multiplication. This interaction of aerobic bacteria and algae, which benefits both, is biologically known as *symbiosis* (Figure 32).

FIGURE 32. Process of symbiotic activities of algae and bacteria in an oxidation pond

(Scale 1 : 30)



O_2 : oxygen produced by algae as well as from the air taken up by bacteria; see the text.

CO_2 : carbon dioxide produced by bacteria, used by algae for conversion into nutrient through photosynthesis

(M) : minerals and other simpler products decomposed by bacteria and converted by algae into algae cells

(OM) : organic matter in the waste, used as nutrient by bacteria; a nutrient can be any form of nourishment, a chemical element or an organic or inorganic compound.

Other natural phenomena come into play in the process of oxidation in the ponds: sedimentation (the settling to the bottom of the pond of material heavier than water); aeration (the supply of air to the water); diffusion (the process of gas flowing from its highest point of concentration to the lowest point, for example the flow of oxygen, concentrated at about 20% in pure clean air, into water, where the concentration of dissolved oxygen is about 5%); and turbulence (the disturbance or movement of water brought about by the current, waves, wind or even fish or other living beings). All these complex factors have to be considered in the design, construction and operation of an oxidation or waste-stabilization pond, in order to achieve satisfactory results.

It should be noted here that, as the name implies, oxidation in the ponds is an aerobic device. However, waste stabilization can also be achieved under anaerobic conditions, or under facultative conditions, which exist in between aerobic and anaerobic conditions.

The reader is referred to Chapter Nine for details of the design, construction and operation of oxidation ponds.

TABLE 13. Absorption area requirements for residences and schools*

Percolation rate: the time required for water to fall 2.5 cm (1 inch), given in minutes	Required absorption area (square metres of absorption at trench bottom per person served)	
	Residences	Schools
2 or less	2.30	0.84
3	2.80	0.93
4	3.25	1.12
5	3.50	1.21
10	4.65	1.67
15	5.35	1.86
30	7.00	2.70
45	8.45	3.10
60	9.30	3.50
Over 60	Unsuitable for sub-surface absorption system.	

*adapted from WHO Monograph Series No. 39 (1958).

7.7. SAND FILTER TRENCHES

Treatment of effluent can also be carried out under aerobic conditions by filtering the effluent over a graded sand filter medium laid out in trenches. The principle of operation is similar to that of filtering water over sand media, except that, in this case, it is effluent that has to be filtered.

The filter medium is constructed in a trench (below ground-level) or above the ground surface, depending on local conditions.

In this process, the effluent is uniformly or evenly distributed over the sand medium, and, as the effluent percolates through the medium, the aerobic bacteria present in the sand digest the organic component of the effluent, the end result being clear stabilized filtrate.

This method can be considered as an alternative method of effluent treatment in places where the absorption capacity of the soil is poor, or where the ground-water table is high, or where adequate space is not available. However, this method is not economically possible for most developing countries, because of the difficulty of obtaining clean sand and gravel in many areas, and the cost and the technical skill needed to construct and operate sand filter trenches.

7.8. CHLORINATION

Another method is to disinfect the effluent with chemicals, particularly with chlorine. But the cost of chlorination cannot be justified for effluent treatment in developing countries, though chlorination is often used to purify drinking-water in urban supplies.

CHAPTER EIGHT

MUNICIPAL SEWAGE TREATMENT AND DISPOSAL IN GENERAL

The individual sewage treatment and disposal methods that have been discussed in the preceding chapters are applicable only to isolated residential areas or small communities. These methods cannot effectively meet the needs of relatively large cities or communities. In these circumstances the responsibility of treating and disposing of sewage is usually entrusted to a city administration, generally known as a municipality.

The term "municipal sewage treatment and disposal" is therefore applied to the safe disposal of a large volume of sewage through complex engineering processes. Of course, the basic principles that have been pointed out in connection with individual sewage treatment and disposal also apply in this context. But the planning, design, construction, operation and maintenance of a municipal sewerage system require specialized knowledge and skills of engineering, known as *sanitary engineering.*

Sanitary engineers or public health engineers, and technicians of various skills, are responsible for the entire process of a municipal sewerage system. Where possible, their work is carried out in accordance with well-developed, well-tested and standardized methods. For instance the drainage systems of individual houses are laid out in accordance with the plumbing codes or methods laid down by the local Health Authority. These codes usually include instructions as to the type, sizes and quality of material to be used, and the gradient or steepness of lines transporting sewage, etc., to be followed.

The processes involved in municipal sewage treatment and disposal can be divided into three phases: (a) the collection of sewage, (b) the transport of sewage by the sewerage system to the place of treatment, and (c) the treatment and disposal of sewage.

8.1. THE COLLECTION OF SEWAGE

Sewage is collected from individual houses, or groups of houses, neighbourhoods, municipal zones, etc., and is discharged into the sewer pipes or sewer lines. The sewer lines from a given area discharge into larger sewers, known to sanitary engineers as main sewers or "mains" (but note that the main water supply pipes are also known as water mains or "mains"). The main sewers eventually become larger and larger until the whole city sewage is transported to the final treatment point.

8.2. TRANSPORT OF SEWAGE BY THE SEWERAGE SYSTEM TO THE PLACE OF TREATMENT

The criteria for the design and construction of the sewerage transport system depend mainly upon the volume of the sewage to be conveyed. As a rule, the minimum size of sewer pipes used is 100 millimetres in diameter. However, depending on the quantity of sewage, the diameter of sewer pipes varies from 100 to 150 to 200 millimetres or more.

The second important factor which determines sizes of sewer pipes is the desired speed or velocity at which sewage must flow in order to avoid the sinking or deposition of the solid component of the sewage in the course of transport. The ideal velocity is that which will create optimum conditions for self-cleansing in a given size of pipe. Accordingly, sewer pipes are laid in such a way as to provide the best gradient or slope speeds that will keep the pipes clean. In a domestic sewerage system, with a minimum sewer-pipe diameter of 100 to 150 millimetres, the optimum velocity is generally 60 to 100 centimetres per second.

As far as possible, a sewerage system is designed to make use of gravity for the flow of sewage. The gradient, technically called "the hydraulic gradient" (the slope down which water flows easily), varies with the diameter of the pipes. Generally the gradient is 1:40, 1:60, and 1:90, if the diameter is 100, 150, and 225 millimetres respectively. For example, if the gradient is 1:40, it means that, in a straight line of 40 metres distance, the fall or "differential elevation" is one metre.

Ideally, sewer lines are laid in straight lines or sections, in order to minimize blockages or the slowing-up effect of bends in the pipes. Obviously, a great deal depends on the topographical features of the area, since the maximum use of gravity - the downhill flow of water caused by the contours of the town involved - is desirable. To ensure the continuous movement of sewage, inspection chambers, called *man-holes*, and *lifting stations* are installed.

Man-holes

Man-holes are entrances constructed to connect the ground surface or road surface with the sewer lines. Man-holes are usually 60 by 60 centimetres or more in diameter, with a variable depth. They are constructed so as to enable a man to enter the upper part of the sewer for the purposes of inspection and the control or removal of blockages. Man-holes are installed along the sewerage system in the following places:

1. At approximately 100 metres' distance when the sewer pipes run in straight lines; but the larger the size of the sewer, the greater the spacing
2. At each change of direction of the sewer lines
3. At each change of size of the sewer pipes
4. At the juncture of two or more sewer lines; that is, where a lateral or side-line joins another pipe, or where a subsidiary line joins the main sewer.

Lifting stations

Lifting stations, lift stations or pumping stations are installed where the natural slope of the area does not permit the use of gravity, or where the sewer lines are too far below the ground level. In these places, the sewage has to be lifted or pumped to a convenient height so that it can again start flowing by gravity. Of course, if the sewage flow is maintained by gravity alone, the additional cost of pumping or lifting will not be needed, but this depends on the topographical features, the slopes and hills and valleys of the area.

8.3. OBJECTIVES OF MUNICIPAL SEWAGE TREATMENT AND DISPOSAL

The main objectives of municipal sewage treatment are (a) to control and prevent the excreta-borne diseases, in this case sewage-borne diseases, and (b) to maintain the ecological balance of water courses, which will be upset if raw or inadequately treated sewage is discharged into them. Any selected method of sewage treatment and disposal must strictly satisfy the criteria set out for human wastes disposal.

Let us note that the term "treatment" is used here in the medical sense. The sewage is literally "sick"; it is potentially dangerous to human welfare, and must therefore be treated before it comes into contact with man's total environment.

8.4. MAJOR FACTORS INFLUENCING MUNICIPAL SEWAGE TREATMENT

There are several well-developed methods for conventional sewage treatment. However, the choice of any one method, or any combination of methods, will depend upon several factors, such as

1. The cost and feasibility of the method
2. The climatic conditions of the country, or of a region within the country
3. The quality and standard of treatment required by the health authorities of a country or city
4. The volume, rate of flow and other conditions of the receiving body of water, if the treated sewage or effluent is eventually to be disposed of into a water-course.

After having considered these and other factors which may be relevant to an area, an appropriate method of treatment is selected by the sanitary engineer.

As municipal sewage treatment and disposal is a highly specialized and complex technology, only the basic principles of the process will be dealt with here.

8.5. PRINCIPLES OF SEWAGE TREATMENT

The main methods of sewage treatment can conveniently be divided into the following processes:

1. Separation of the solid component of the sewage from the liquid
2. (a) Reduction of the decomposable organic matter in the sewage, that is, reduction of the B.O.D. of the sewage to the lowest possible level, and then (b) stabilization of the sewage by bacterial action or through a chemical process
3. Conversion of the sludge of the sewage to an inert and inoffensive state by a biological or chemical process
4. Destruction of pathogenic organisms through the processes 1 to 3, listed above.

Before we discuss some of the common treatment methods practised in conventional sewerage works, however, it may be valuable to repeat some of the principles already stated, with regard to sewage.

Suspended solids

Domestic sewage is normally composed of roughly 99% water and 1% solids. Out of that 1%, the suspended solid component makes up the largest and most important proportion of the sewage. From the point of view of health also, as we said in Chapter Five, it is the most important component, because it is here pathogenic organisms will be found. Furthermore, it is the suspended solid component of sewage which exerts the highest proportion of biochemical oxygen demand (B.O.D.) in sewage treatment.

Therefore, for the purposes of treatment, it is useful to know the daily contribution of suspended solids per person, and the number of the local population, as this will help to determine the strength of the sewage. However, the daily contribution of solids (the major component of excreta) depends upon the type of food and the eating habits used by a community.

Mixed with the usual large quantity of flushing water, the suspended solids form a significant but very small component of sewage. Consequently they are generally expressed in terms of parts per million (P.P.M., or milligram/litre).

Biochemical oxygen demand (B.O.D.)

The biochemical oxygen demand of sewage is the oxygen required to stabilize the organic matter in sewage. The B.O.D. is the most important means for measuring the strength of sewage or waste-water; that is, for measuring the proportion of unstable organic matter, which can be decomposed - or mineralized - by bacterial action.

The strength of domestic sewage of a community will vary with the hour, the day of the week and the season of the year. However, generally speaking, the strength (B.O.D. level) of domestic sewage of a particular community will be more or less constant, because the average contribution of suspended solids and waste-water per capita per day is about the same.

In industrialized and developed countries, where organized sewage systems have been in practice for many years, the daily sewage flow, the contribution per capita of suspended solids, and the level of B.O.D. requirement are well recorded, and values have been established. The B.O.D. value for expressing the strength of sewage is well-known and commonly used in sewerage works. Whether with regard to the domestic sewage of a particular community, or the wastes of a specific industry, the strength is generally expressed in terms of "the five-day B.O.D." (measured at 20°C).

The 5-day B.O.D.

According to this value, the 5-day B.O.D. of fresh domestic sewage is 100 to 300 P.P.M., or more, depending on the habit of diet and the daily water consumption. The B.O.D. level of industrial wastes is generally much higher, depending on the nature of the content of organic wastes. The 5-day B.O.D. value does not represent the total value of oxygen needed for complete stabilization of the sewage or waste-water, but, because the original tests were performed within a period of five days, the term has become a referral point for expressing B.O.D. In practice, however, the 5-day B.O.D. indicates about 60% to 80% of the total oxygen demand of domestic sewage or industrial wastes.

In summary, we must remember that knowledge of (a) the daily sewage flow, (b) its suspended solids, and (c) the B.O.D. level it will exert on the receiving body of water, is essential information required for treatment of sewage or waste-water.

The B.O.D. of effluent

The quality of sewage treatment is also judged on the basis of B.O.D. of the effluent. The public health authorities of a city or state set the level of B.O.D. of effluent as one of the main criteria for sewage treatment. The requirement of many developed countries limits the B.O.D. level of effluent to a maximum of 30 mg per litre, but the most desirable level is between 20 mg/l and 10 mg/l. However, in developing countries, a compromise at a higher level may be essential.

Sewage treatment and water pollution

The dumping of raw or inadequately treated sewage into surface waters, such as a stream, river, lake or the sea-shore, has been one of the common practices of sewage disposal systems. Perhaps a century ago this practice was tolerable because of the relatively low population and small amount of sewage produced.

However, the high population growth and concentration in cities, the rise of living standards and the development of industries have immensely increased the volume of sewage as well as its complexity in composition. Consequently, the indiscriminate discharge of this large and complex quantity of sewage resulted in health hazards, intolerable nuisances, and ecological imbalance in the receiving bodies of water.

As we have pointed out previously, when raw sewage or effluent is discharged into a natural body of water, the dissolved oxygen (D.O.) which is present in the water is quickly reduced or depleted. This is because the oxygen demand of the incoming sewage has to be satisfied through taking up the D.O. present in the water.

We have said that the average domestic sewage has a B.O.D. level of 100 to 300 mg/l. The effluent, depending on the degree of treatment, may have a B.O.D. level of 30 mg/l to 80 mg/l. Under normal conditions, the B.O.D. level of natural water (unpolluted rivers, streams, etc.) is about 1 to 2 mg/l. It is clear, then, that the incoming sewage or effluent needs a considerable amount of oxygen, which has to be supplied from the D.O. of the receiving body of water. If the volume of incoming sewage or effluent is comparatively small or if its B.O.D. level is low, the receiving water can manage to regain its D.O. through the natural process of self-purification.

However, if the volume of incoming sewage or effluent is more than the stream can cope with, fish and other aquatic life will be gradually destroyed due to the inadequacy of the D.O. to satisfy their oxygen needs. Consequently the stream then loses its ecological balance, and becomes an offensive sight, with a foul smell.

The spread of pathogenic organisms through this polluted water is more than probable. In addition, sewage originating from industrial sources may pollute the receiving waters with poisonous chemicals, depending on the nature of the wastes.

The main purposes of proper treatment and disposal of sewage are therefore to control pollution of water sources, and consequently to prevent communicable diseases and safeguard human welfare.

In developing countries like Ethiopia, where a large segment of the population directly uses the untreated waters of streams, river, lakes, etc. (for drinking, washing themselves, washing utensils for food, and for other purposes), protection of these waters from sewage pollution is undoubtedly an essential public health measure. Since many countries have, after a struggle, established from experience standard requirements, rules and regulations for sewage treatment and disposal, it should not be impossible for Ethiopia to learn to follow these countries' guidelines.

CHAPTER NINE

THE PHYSICAL PROCESSES USED IN MUNICIPAL SEWAGE TREATMENT AND DISPOSAL

The processes involved in municipal sewage treatment are quite complex, but, in general, the processes may be physical, biological, chemical or a combination of some or all. The selection of a specific treatment process will be determined by the designing engineer, who has to take into account all the factors we have noted.

In this book, only the fundamental principles of the processes will be dealt with, for the benefit of non-technical people in the field. We shall omit the chemical processes, which are in general too expensive to be practicable in most developing countries.

9.1. SCREENING

Raw sewage is likely to contain relatively large objects such as rags, sticks, leaves, paper, pieces of broken glass, etc., which must be removed before the sewage undergoes a treatment process. These objects are blocked by screening, with screens. Screens are simply frames containing thin iron bars, which hold back and remove the unwanted objects during the flow of sewage.

Screens are usually called *coarse screens* if the bars or grills are placed 2 cms to 3 cms apart, and *fine screens* if the bars are placed 1.5 cms or less apart. Fine screens are commonly made of wire mesh, or of perforated metal plates. The objects retained by the screening are usually disposed of by hand (manually), or mechanically, at fixed intervals of time.

9.2. THE GRIT CHAMBER

The term "grit" refers to inert materials such as sand, gravel, cinders, fine glass, seeds, etc., which may be present in the sewage. If the materials are not removed before the sewage enters the treatment unit, they are likely to block the unit and interfere with its proper functioning.

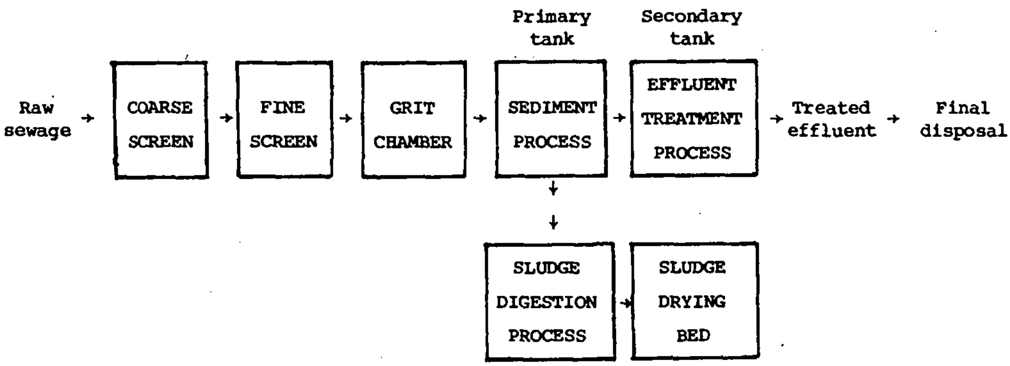
These materials are removed by grit chambers (Figure 33). Grit chambers are designed and constructed to slow down the speed of the incoming sewage for a short time, just long enough to let these small objects settle to the bottom of the chamber, without interfering with the regular flow of sewage.

9.3. THE SEDIMENTATION PROCESS

Sedimentation is one of the most commonly used processes of sewage treatment. In some cases, it may be the only sewage treatment process before final disposal into a water course. The sedimentation process takes place in a tank or series of tanks, the shape and size of which will depend upon the volume of sewage and the retention period.

A sedimentation tank may either accomplish the physical process of separating the settleable sewage from the non-settleable sewage, or the biological process of anaerobic or aerobic decomposition, depending on the intent of the designer. As stated earlier, much of the polluting material in raw sewage is in the form of suspended insoluble particles. The purpose of the sedimentation process is to remove as much as possible of this material.

FIGURE 33. Flow chart
of a typical municipal sewage treatment process



Depending on the retention period, most of the suspended matter is deposited in the bottom of the tank and forms sludge. The accumulated sludge is removed periodically from the sedimentation tank, manually or mechanically, and is discharged into a sludge digestion chamber (see below), from which it is further removed to a sludge-drying bed as required (Figure 33).

9.4. THE SLUDGE DIGESTION CHAMBER

As has been explained earlier, sludge is that component of sewage that settles to the bottom of a settling tank during the process of sedimentation. Depending on the type of the treatment process (plain sedimentation, septic tank, Imhoff tank, etc.) and on the retention period, sludge may be termed partially digested sludge, or digested sludge.

Whenever the stage may take place, sludge must be treated separately from the effluent. This separate treatment process takes place in a *sludge digestion chamber* (Figure 33).

In municipal sewage treatment, the sludge is removed mechanically or by gravity system to a sludge digestion chamber. Here the sludge is allowed to be digested by anaerobic bacteria, by creating favourable conditions for anaerobic digestion, such as a predetermined retention period with a favourable temperature.

After the sludge is completely digested (as determined by the operator), it is removed to a *sludge-drying bed.* Here the water contents of digested sludge are removed by drying the sludge in the open air, or by filtering the water in a de-watering unit, i.e. over a porous medium which filters out water and leaves dried sludge. The dried sludge may be used as fertilizer or for other purposes.

Usually, the entire municipal sewage treatment is carried out as a mechanically controlled process; the sludge-digestion and the sludge-drying process are two of the steps in the process.

9.5. THE BIOLOGICAL PROCESS

The treatment of sewage or organic wastes through the biological process is one of the oldest, commonest and relatively less expensive methods in practice.

In the *nitrogen cycle* (Chapter Five), we observed that unstable, decomposable organic wastes are converted into simpler compounds, and finally stabilized by the action of micro-organisms. In nature this process takes a long time, and is usually incomplete, unsatisfactory, and quite likely to create offensive and harmful conditions, including the spread of pathogens.

In the biological process of sewage treatment, this natural phenomenon is brought about under scientifically designed and controlled conditions. The essential part of the process centres on the activities of various forms of micro-organisms, particularly bacteria. In order to understand how the biological process of sewage treatment works, a fundamental knowledge of microbiology is essential.

We have noted earlier that bacteria are grouped into three categories, according to their oxygen intake requirement:

1. **Aerobic bacteria** - those which grow and live in the presence of free oxygen (molecular oxygen);
2. **Anaerobic bacteria** - those which live and thrive only in the absence of free oxygen;
3. **Facultative bacteria** - those which live in the presence or absence of free oxygen.

Sanitary engineers take into consideration these facts as well as other relevant factors in the design, construction and operation of biological treatment plants.

9.6. PRIMARY AND SECONDARY TREATMENT IN MUNICIPAL SEWAGE SYSTEMS

Referring to the municipal sewage treatment flow chart (Figure 33), we see that, after the screening and grit chamber processes, the sewage is led into a sedimentation tank or series of tanks, depending on the volume of sewage. Here, most of the suspended organic matter settles down at the bottom, and, if the retention period is adequate, *anaerobic* decomposition will take place. The process is similar to that which takes place in a septic tank or Imhoff tank. The difference is in the volume of sewage to be treated, and this is taken into account in the design of the plant.

After sedimentation, the effluent undergoes the secondary treatment. Generally the conventional treatment processes are quite complex and highly mechanized. However, they all have a basic method in common, that is, the decomposition or stabilization of organic wastes takes place under *aerobic* conditions. Some of the aerobic treatment processes designed by sanitary engineers are as follows:

1. **Filtration,** represented here by
   (a) Intermittent sand filters, and
   (b) Trickling sand filters
2. **The aeration process,** represented by the activated sludge process
3. **Oxidation ponds.**

9.7. THE INTERMITTENT SAND FILTER PROCESS

The intermittent sand filter consists of a layer of sand media with underlying drain-pipes to carry off or drain away the treated effluent. As in the water filtration system, the drain pipes are laid at the bottom, with crushed stone or gravel of a specified size and depth spread over them, and sand is spread over the gravel to a depth of about 45 cms. The effluent is then dispersed evenly over the sand medium intermittently, with pauses to let the effluent filter through the sand.

While the effluent filters through the sand, the organic matter in the effluent is strained and stabilized by aerobic bacteria in the sand, and the treated effluent (with a very low level of B.O.D.) is then carried away through the drain-pipes to a final disposal site.

9.8. THE TRICKLING SAND FILTER

In this process the sand filter medium is designed and constructed similarly to that in the intermittent process, but the effluent is spread over the sand bed at a predetermined rate, and is literally allowed to trickle through the media. Again, digestion of the organic matter in the effluent is brought about aerobically. The end result is effluent with a permissible level of B.O.D. for its final disposal on a land surface or in a body of water.

9.9. THE ACTIVATED SLUDGE PROCESS

The term "activated sludge" refers to sludge which has been impregnated with masses of aerobic bacteria through a mechanical process of aeration or oxidation. This oxygenated or activated sludge is added to settled sewage that is to be treated. The organic wastes in the settled sewage are stabilized by these masses of aerobic bacteria under strict aerobic conditions.

In a conventional activated sludge process, the raw sewage first passes through the screening and grit chamber processes, and is then led to the sedimentation tank. In the sedimentation tank, the sewage is thoroughly mixed with the activated sludge in order to facilitate aerobic stabilization. Strict aerobic conditions are maintained in the tank by providing mechanical aerators for oxygenating the sewage, hence the name "aeration" process. The length of contact time between the activated sludge and the sewage to be treated, the mechanism of maintaining aerobic conditions, and the degree of treatment to be achieved are predetermined by the designer of this treatment unit, which is sophisticated and expensive, requiring skilled operators.

After stabilization has taken place, a small portion of the sludge deposited in the tank is recycled, or sent back again, to mix with the sewage as it enters the sedimentation process, in order to stimulate the aerobic action there, while the major portion of the sludge is removed to a sludge disposal site. The resulting effluent is generally of a very low B.O.D. level, so low that the effluent may not necessarily require further treatment before its final disposal. .

9.10. OXIDATION PONDS, OR WASTE-STABILIZATION PONDS

An oxidation pond, also called a waste-stabilization pond or lagoon, is a relatively shallow body of water contained in a hollow of predetermined shape dug in the ground, and designed for the purpose of treating sewage (waste-water) or effluent. A brief description of the principles of the oxidation process for treating raw sewage or effluent has been presented in Chapter Seven. There we learn that the function of an oxidation pond depends upon the interaction of *bacteria* and *algae,* and to a lesser degree on other organisms in the pond. This interaction is influenced by natural phenomena, such as the intensity and frequency of sunshine in the locality, temperature, wind, aeration, diffusion, rainfall, etc.

As was said earlier, a basic knowledge of microbiology is essential in order to understand properly how an oxidation pond functions.

Oxidation/stabilization ponds are usually classified in accordance with the nature of the biological activity that takes place, as aerobic, anaerobic or facultative (aerobic-anaerobic) ponds.

Since the end result of all three processes - aerobic, anaerobic and facultative - is stabilization, the term "stabilization pond" or "waste-stabilization pond" will be used from now on in this text.

Advantages of waste-stabilization ponds

Compared with other sewage treatment processes, waste-stabilization ponds have the following advantages:

1. They are relatively simpler to design, construct, operate and maintain.
2. Less capital and less operating and maintenance costs are needed, especially in places where adequate land is available.
3. They are more efficient in destroying pathogenic organisms - bacteria, intestinal parasites and their eggs, - mainly because of the long retention time.
4. They are more appropriate for tropical developing countries like Ethiopia, where land is easily available and climatic conditions are favourable.
5. They can be applied to the treatment of raw sewage, effluent, or other organic wastes.

Disadvantages of waste-stabilization ponds

1. An extensive area of land is required.
2. The waste-stabilization pond cannot deal with certain industrial wastes.
3. The problem of smell may arise when the system is constructed near a community.
4. The achievement of a desired standard of suspended solids may be difficult.
5. The effluent may be choked in algae.

As stated earlier, commonly all stabilization ponds are ditches dug in the ground, not very deep, but the depth varies, depending on the type of pond. The excavated earth is usually heaped up to construct earth walls or banks, in order to prevent access of animals to the pond, and to lessen mosquito-breeding, since mosquitoes tend to breed in very, very shallow water, such as might spread round the pond if it did not have a wall or bank. Different types of waste-stabilization ponds have different purposes, and are often used consecutively, one after the other, as shown below.

9.11. ANAEROBIC STABILIZATION PONDS

As the name shows, anaerobic ponds function under anaerobic conditions. As in a septic tank, decomposition is brought about by anaerobic bacteria, and the resulting sludge has to be removed periodically. The depths of these ponds generally vary from 2 to 4 metres. The retention time also varies widely with climatic conditions, but commonly extends from 2 to 10 days or more.

Anaerobic ponds are used for handling strong organic wastes and wastes for which initial oxygen demands would exceed the capabilities for operating in other types of ponds. They are used particularly where organic industrial wastes must be treated, and the treated wastes may then be passed on to a facultative pond.

9.12. FACULTATIVE PONDS

The stabilization of wastes in facultative ponds depends upon the activities of facultative bacteria. Hence, the design, construction and operation of these ponds have to take into consideration the optimum conditions required for these organisms to flourish.

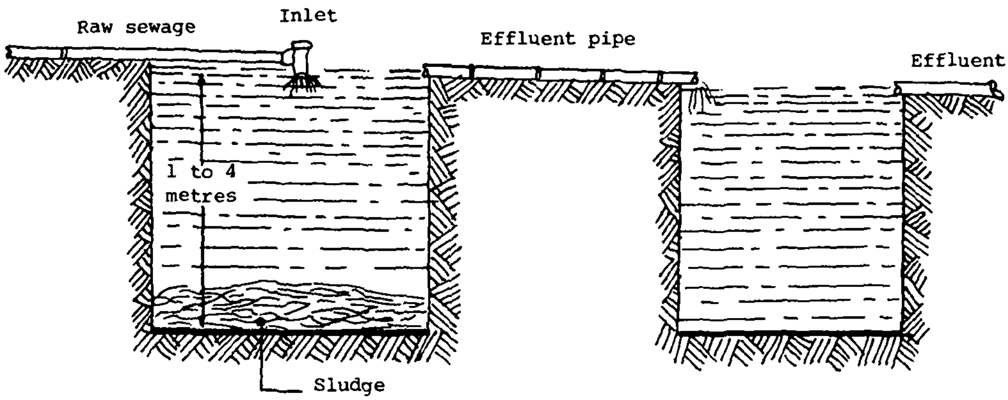
The depths of facultative ponds vary from 1 to 1.5 metres, while the retention time may extend from 5 to 30 days or more. It should be remembered that aerobic decomposition takes place in the upper layers of these ponds, and in the lower layers anaerobic decomposition takes place. Facultative ponds are often used for domestic sewage, and for a variety of organic industrial wastes.

9.13. AEROBIC PONDS

Aerobic ponds function by the action of aerobic bacteria. Under a municipal sewage treatment process, these ponds usually receive effluent from the facultative or anaerobic ponds for final maturing or stabilization; hence they are sometimes called *aerobic maturation ponds*. The depths of aerobic ponds usually vary from 1 to 1.5 metres, and the retention time may extend from 5 to 10 days or more (Figure 34). Aerobic ponds are used primarily where organic matter in waste-water is mainly in soluble form, e.g. effluent from a primary treatment pond or from a biological treatment system.

FIGURE 34. Schematic view of a waste-stabilization pond

(Scale 1 : 30)



Note 1. The inlet should preferably be placed in the centre of the pond, in order to facilitate quick mixing of the incoming sewage, and to speed up the even distribution of the sludge.

Note 2. The depth and retention time is governed by such factors as the B.O.D. concentration load and climatic conditions, and also by the type of pond.

Area and loading rate of waste-stabilization ponds

The number, surface area and loading rate per unit area of waste-stabilization ponds are influenced by many factors, including the volume and strength of sewage to be treated, the quality of treatment required, and the climatic conditions of the locality, i.e. sunshine, wind, temperature, rainfall, rate of evaporation, etc.

Since these factors vary from place to place, each designer must develop his own criteria to suit the specific locality.

Nevertheless, a single stabilization pond can hardly give a satisfactory result. Therefore, it is a common practice in the design and construction of a stabilization pond system to have a series of ponds. The series can be constructed in an appropriate combination of anaerobic, facultative and aerobic ponds, the number of each being determined by the designer. A typical layout is shown in Figure 35. Here the raw sewage is first led into anaerobic ponds, followed by facultative ponds and finally by aerobic maturation ponds.

FIGURE 35. A typical lay-out of waste stabilization-ponds

Raw sewage → → [Anaerobic pond] → [Facultative pond] → [Aerobic pond] → Effluent

	Anaerobic pond	Facultative pond	Aerobic pond
Depth of pond:	2 - 4 metres	1 - 1.5 metres	1 - 1.5 m
Retention time :	1 - 5 days	5 - 30 days	5-10 days or more

With regard to the loading rate, it is difficult to give an exact formula for all conditions. However, for climatic conditions such as those in Ethiopia, with - in many areas - "tropical, uniformly distributed sunshine and temperature, and no seasonal cloud cover", Gloyna (1971; see References) recommends the addition of a load of organic waste of 150 to 360 kilograms B.O.D.$_5$ per hectare (1 hectare - 10,000m^2), for a population per hectare of 3000 to 7000 people, with a retention time of 17 to 33 days for a facultative pond. We should note, however, that this loading rate is based upon several assumptions which are affected by specific local conditions.

The loading rate and the retention period can also vary from one stabilization pond to another in a series of ponds, depending on the purpose for which each pond is used. For example, the first pond in a series can be designed to remove a certain percentage of the B.O.D., while the second pond will destroy pathogenic organisms, and so on.

With such methods, well-planned waste-stabilization ponds usually produce effluent which is very low in B.O.D., and almost completely free from pathogenic organisms.

Nevertheless, regardless of the purity of the effluent, the discharge of effluent into any receiving body of water or onto any land surface must first be approved by Public Health authorities.

9.14 GENERAL REMARKS ON THE APPLICABILITY OF A MUNICIPAL SEWERAGE SYSTEM TO TOWNS AND CITIES IN DEVELOPING COUNTRIES

The conventional municipal sewerage system is essentially a system which has been developed and effectively used in developed and industrialized countries for many years.

When applied to developing countries it has several drawbacks which make its adoption virtually impossible; some of these are given here:

1. The system requires the presence of adequate quantities of piped water in the home for flushing. Considering this factor alone, the cost of the large amount of water required daily for flushing a standard toilet is likely to be beyond the economic means of an average family in many developing countries.
2. It requires the installation of rather expensive sanitary equipment in the home.
3. It requires an intricate network of underground piping for conveying sewage from homes to the final disposal place.
4. The laying of the network of piping system (the sewerage system) needs an initial capital investment which is generally beyond the economic means of the vast majority of developing countries. Furthermore, the installation of the network of pipes becomes more complicated and costly in places where units of the population live far apart, and particularly in cities or towns which are not properly planned.
5. At the site of the final disposal treatment, a method has to be provided to purify the sewage before discharging it into a water-course or onto a land surface.

Taken as a whole, these factors make the wider application of an up-to-date sewerage system economically impossible for most of the developing countries.

However, we have discussed several possible means for the safe disposal of human wastes, and some may be applicable to different areas and situations in Ethiopia - indeed, many are in use. The spread of knowledge of how to apply one of these systems, and continuing education in its use, could greatly influence the status of local health for the better. Some areas even in developed countries still suffer from certain forms of excreta-borne diseases, but communities in the majority of these countries have ensured improved conditions, and have thus improved standards of health and living. Health professionals and other development workers took and continue to take the responsibility of making their people understand the problems, and convincing them of the benefits to be derived. There is no good reason why Ethiopia cannot follow the trend towards safety and better health.

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GLOSSARY

The contracted form "adj." is used for "adjective" in this Glossary. Where a word has meanings other than the meaning used in this book, the instruction "See also dictionary" is added to the definition.

Where a term is adequately defined in the text, the term is not necessarily included in this Glossary.

ablution (noun): washing one's body
absorb, to (verb): to have the ability to take in liquid or semi-liquids. See also dictionary.
  absorption (noun)
  absorbent (adj.)
absorption (noun): see **absorb, to**
abundant (adj.): plenty
  abundance (noun)
access (noun): entrance, ability to enter
acid (noun): a bitter, corrosive substance or compound that can react with an alkali to form a salt. See also dictionary.
activate, to (verb): to make something change or move. See also dictionary.
adapt, to (verb): to alter to make suitable
  adaptation (noun)
  adaptable (adj.)
adequate (adj.): enough for a given purpose or requirement
adopt, to (verb): to take up or accept as one's own a plan, method, child, etc.
  adoption (noun)
aerator, (noun): something that supplies air (oxygen)
  aerate, to (verb)
  aeration (noun)
aerobe (noun): a micro-organism which can thrive in the presence of oxygen
aerobic (adj.): living or growing in the presence of free oxygen; containing organisms which need free oxygen (e.g. aerobic pond). See also **bacterium.**
aetiology (noun); U.S. spelling, **etiology:** a science which deals with the causes of disease
  aetiologic, aetiological (adjectives)
agent (noun): something that actively produces or causes a result; e.g., a bacillus may be an agent of infection. See also dictionary.
air sac: see **sac**
algae (plural noun): very simple forms of plant life, found in water or damp places
alkali (noun): a substance which can combine with acid and form a salt, making the acid ineffective
  alkaline (adj.)
alveolus (singular noun), **alveoli** (plural noun): a hollow structure or pouch for air, found in the lung. See also dictionary.
  alveolar (adj.)
anaerobe (noun): a micro-organism that grows and thrives only in the absence of free oxygen.
anaerobic (adj.): living or growing in the absence of free oxygen; containing anaerobic organisms (e.g. anaerobic pond). See also **bacterium.**
aqua (noun, Latin): water
  aquatic (adj.)
arthropod (singular noun), **arthropoda, arthropods** (plural nouns): literally, "with jointed legs": a member of a group of living things including insects, mites and other zoological classes
assimilate, to (verb): to take in or absorb completely, so that whatever is taken in becomes part of the substance. See also dictionary.
assumption (noun): belief or supposition. See also dictionary.
  assume, to (verb)
auger (noun): a tool which can be turned or rotated to make a hole .
bacillus (singular noun), **bacilli** (plural noun): a genus of aerobic, rod-shaped cells; also, in non-technical language, any rod-shaped micro-organism.
bacterium (singular noun), **bacteria** (plural noun): a micro-organism, biologically intermediate between an animal and.a plant. It multiplies by simple cell division, and can grow outside or inside an animal body, including a human body. Bacteria which are capable of causing diseases are called pathogenic bacteria or pathogens. But not all bacteria are harmful; some are useful to man, because they cause the natural breaking-down of organic matter into a more simple and less dangerous form.
In accordance with their intake of oxygen, bacteria can be classified into two large groups, (a) aerobic bacteria which obtain their oxygen supply from the air (free oxygen) or thrive in the presence of free oxygen, and (b) anaerobic bacteria, which cannot live in free oxygen.

baffle (noun): a plate or other mechanism for stopping or turning in another direction the flow of a liquid. See also dictionary.
bail out, to (verb with adverb): to empty, to remove a fluid or semi-fluid from a container. See also dictionary.
bale out, to: see **bail out, to**
bamboo (noun and adj.): a plant with hollow, woody stems
bank (noun): a heap, pile or ridge of earth. See also dictionary.
bin (noun): a container used for storage
biochemical (adj): dealing with the chemistry of plant and animal life
biologic, biological (adjectives): dealing with plants and animals
biology (noun)
B.O.D. (initials of noun phrase): biochemical (or biological) oxygen demand; the amount of oxygen needed to stabilize organic matter through the action of bacteria
bore, to (verb): to make a hole. See also dictionary.
cadre (noun): a group of trained personnel who can train others
capacity (noun): measured size to hold liquids or solids. See also dictionary.
capita (plural noun, Latin): see **per capita**
capsule (noun): a small case or sac-like structure enclosing, e.g., the egg of a parasite. See also dictionary.
carbolic acid (noun phrase): a commonly used name for phenol, a chemical used in a weak form as a disinfectant
carrier (noun): a person who sheds organisms capable of causing disease, without showing symptoms of the disease himself. See also dictionary.
case (noun): an example of disease or injury. This word should not be used to refer to a patient, the person who has a disease or injury. See also dictionary.
causative agent (noun phrase): an organism which causes illness
cell (noun): a very small unit of living matter. See also dictionary.
cess (noun): sewage and other liquid or partly liquid wastes
cesspool (noun): a tank or other container for collecting sewage and other liquid wastes, which are then drained into the surrounding soil
cestode (noun): a tapeworm, a flatworm
chute (noun): a channel or pipe through which fluids can fall to a lower level
cistern (noun): a tank for holding water
cleanse, to (verb): to make clean
clog, to (verb): to fill up and prevent movement because of dirt or other substances
closet (noun): the bowl used for excreta and urine in a water closet system; originally, a small private room
coliform (noun and adj.): the type of bacillus which affects the colon or large intestine
communicable disease (noun phrase): a disease which can be transmitted from man to man or from other animal to animal or between man and animals, either by direct contact, or through discharges, or through a vector, e.g. flies
complex (adj.): formed by two or more substances, in a relationship often complicated or difficult to explain in detail
compost (noun): a mixture composed mainly of decayed organic matter, used as a fertilizer
compound (noun and adj.): a substance formed by several different substances. See also dictionary.
constituent (noun and adj.); a part helping to make up a larger unit or substance. See also dictionary.
construct, to (verb): to make, to build
construction (noun)
contact (noun): a person who has been in recent close association with the source of a communicable disease. See also dictionary.
contact, to (verb): to touch
contagious (adj.): spreading by contact or touch
contaminant (noun): a substance that infects, pollutes, or makes something unfit for use
contamination (noun): the presence of an infectious agent on a body surface, in a wound, in water, food, milk, on the soil, etc.
contaminate, to (verb)
contour (noun) the outline of rising or sloping ground
cope with, to (verb and preposition): to deal with (e.g., some difficulty) successfully
corrosion (noun): the weakening or wearing away or eating away of a material by chemical action
corrode, to (verb)
corrosive (adj.)
corrugated iron (noun phrase): sheet iron or steel made with regular parallel hollows and ridges
criterion (singular noun), **criteria** (plural noun): a suitable, safe level or standard of quality used as a base for plans or decisions. See also dictionary.
crude (adj.): natural, without additions or treatment. See also dictionary.
curbed well (noun phrase): a well with a raised protective frame or wall round its mouth. The wall is known as a **curb** or **kerb**. See also dictionary.

cycle (noun): a series of events which follow one after the other, with the last happening starting the first happening again, as if in a closed circle. See also dictionary.
cyst (noun): a sac or pouch with a wall of membrane, developed by parasites. See also dictionary.
data (plural noun), **datum** (singular noun): factual information which is given or available
debility (noun): weakness
decompose, to (verb): to decay, to be chemically broken up into other substances. See also dictionary.
decomposition (noun)
defaecate, to; U.S. spelling, **defecate, to** (verb): to discharge faeces from the bowel
degradable (adj.): able to be broken down in form, able to be digested
demineralize, to (verb): to remove the crystalline chemical forms
depletion (noun): reduction; making less in quantity
deplete, to (verb)
deposit (noun and verb): matter placed or dropped or settled at the bottom of a liquid; to set something down. See also dictionary.
desludge, to (verb): to remove decomposed sewage, or other mud-like material
device (noun): an apparatus or instrument invented for a special purpose. See also dictionary.
diffusion (noun): spreading out
digestion (noun): breakdown or decomposition of organic matter into simpler substances, normally under anaerobic conditions. See also dictionary.
digest, to (verb)
dimensions *(plural noun): measurements, size*
diminish, to (verb): to become less, to become smaller
discharge, to (verb): to send out, to pour out. See also dictionary.
discharge (noun)
disinfectant (noun): a chemical that destroys some types of harmful or harmless micro-organisms
dissolve, to (verb) : to become completely mixed in water, to become a solution in a fluid
distribution box (noun phrase): a mechanism used to equalise the flow of effluent into various tile lines or pipe lines in a disposal field. See also dictionary.
D.O. (initials of noun phrase): dissolved oxygen; oxygen existing in clean water
dome (noun): a rounded upper part
drain (noun): a man-made channel by which liquid or other matter is taken away
drain, to (verb)
drainage (noun): the process or system of removing liquids
dumping (verb-noun): the practice of dropping or throwing down heaps of rubbish, etc., without thinking of possible harm that may be caused
dump, to (verb)
dump (noun): a mound or heap formed by rubbish, garbage, etc.; the place where it is thrown
dysentery (noun): a disorder of the bowel caused by an infection and usually resulting in diarrhoea with blood and mucus in the faeces. Amoebic dysentery is caused by *Entamoeba histolytica,* and bacillary dysentery is caused by a bacterium of the genus *Shigella.*
earthenware (noun, singular form only, and adj.): articles made of clay; *glazed earthenware* is clay given a shiny, protective coating to make it non-porous.
ecology (noun): the study of plants and animals in relation to their environment and interaction with each other
ecological (adj.)
effluent (noun): a liquid that flows out; waste-waters
elevation (noun): height
eliminate, to (verb): to remove; to get rid of waste matter from the body
embryo (noun): the early form of developing life
embryonic (adj.)
embryonate, to (verb): to become an embryo or to produce an embryo
enamelled (verb-adjective): painted with a shiny protective covering
encapsulate, to (verb): to form or surround by a protective case
engineer, to (verb): to plan, construct and manage
engineer (noun, personal)
engineering (noun)
environment (noun): surrounding; conditions influencing life
environmental (adj.)
epidemiology (noun): the study of the distribution and movements of disease among living things
epidemiologic, epidemiological (adjectives)
excavated (verb-adj., passive): dug out and removed, e.g. earth from a ditch. See also dictionary.
excavate, to (verb)
excrement (noun): waste matter, especially faeces and vomit
excreta (plural noun): waste matter, especially faeces and vomit

excrete, to (verb): to cause to pass out of the body
factor (noun): a fact that contributes to a result; something that must be considered when making a plan. See also dictionary.
facultative (adj.): able to live and flourish in more than one set of conditions. See also dictionary.
facultative pond (noun phrase): a body of water in which aerobic and anaerobic bacteria can live and thrive
faeces; U.S. spelling, **feces** (plural noun): body wastes discharged from the bowel
faucet (noun): a tap, a device to control the flow of water, to turn it off or on
feasible (adj.): able to be done or brought about successfully
  feasibility (noun)
fertilize, to (verb): to spread a substance that will nourish plants, etc.; to cause to embryonate. See also dictionary.
  fertilization (noun)
fertilizer (noun): natural or artificial substance used to make plants grow well
fibre; U.S. spelling **fiber** (noun): thread-like material such as grass-roots, strips of tree-bark, animal hair, etc.
filter (noun): a material or mass of material (e.g. sand) which will separate matter from water when both are passed through it. See also dictionary.
  filter, to (verb)
filtrate (noun): the fluid that has passed through a filter
filtration (noun): the action of filtering
fixture (noun): an object fixed or fastened firmly in position, often in a house
flourish, to (verb): to grow well, to live and increase in a state of healthy activity. See also dictionary.
fluid (noun and adj.): a liquid or a mixture of liquids and solids which can flow and move freely in the shape of its container
fluke (noun): a worm with a flat shape, a flatworm. See also dictionary.
flush, to (verb): to flow out, to cause a liquid to flow out. See also dictionary.
flush toilet (noun phrase): a water closet with a device for cleansing it with a flow of water
focus of infection (noun phrase): an infected person, or an object such as faeces, from whom or which disease might arise or spread
foul, to (verb): to make dirty. See also dictionary.
  foul (adj).
free oxygen (noun phrase): oxygen that is available and able to be used, not closely combined with another gas or liquid
fungus (singular noun), **fungi** (plural noun): a member of the plant division Fungi, which includes moulds mushrooms, mildew, etc.
funnel (noun): a cone-shaped article with a pipe or tube at its base, to catch and carry fluids in a given direction
garbage (noun): solid wastes, such as waste food or vegetable matter, or objects thrown away
gastrointestinal (adj.): belonging to the stomach and all other organs involved in the digestion of food and passing it out of the body
genus (noun; plural noun **genera**): a group of species of plants or animals that have similar characteristics
glazed (adj.): see **earthenware**. See also dictionary.
gradient (noun): slope going up or down; the measurement of the slope's ascent or descent
gravel (noun and adj.): loose small stones or fragments of rock
gravity (noun): the natural force attracting objects to the lowest point that they reach on earth
habitat (noun): the natural home of a plant or animal
helminth (noun): a parasitic worm
horizontal (adj.): flat, level, parallel to the horizon (the line where earth and sky seem to meet)
host (noun): the living animal (including man) that gives nourishment and/or a place to live to an agent of infection. See also dictionary.
humus (noun): fertile earth or soil containing decayed vegetable and animal matter
hydraulic gradient (noun phrase): the slope down which water finds its easiest path to flow
immunity (noun): resistance to infection
  immune (adj.)
impermeable (adj.): not allowing liquid to penetrate or trickle through, not able to be permeated
impregnate, to (verb): to fill, to cause to be filled, to mix with. See also dictionary.
indiscriminate (adj.): without thought or judgment
inert (adj.): without power to move, not active
infect, to (verb): to pass a disease on to a person or object
  infection (noun)
  infectious, infective (adjectives)
infiltration (noun): the process of passing through a substance such as earth
  infiltrate, to (verb)
ingest, to (verb): to swallow, to take into the stomach for digestion

initial (adj. and noun): at the beginning; the first letter of a word
insoluble (adj.): not able to be dissolved. See also dictionary.
install, to (verb): to put in, to place
intermittent (adj.): stopping and then starting from time to time, not continuous
intestine (noun): the internal parts of the body which deal with digestion and absorption of food (small intestine) and elimination of unwanted matter (large intestine)
irrigate, to (verb) : to supply water for agricultural land, often through man-made channels
irrigation (noun)
irrigation tile: see **tile**
lagoon (noun): a shallow man-made pond used for the natural oxidation of sewage. See also dictionary.
larva (singular noun), **larvae** (plural noun): the immature stage of an insect, when it hatches from the egg; it often resembles a worm, and later passes through other changes.
larval (adj.)
lateral (adj. and noun): at the side; a drain or pipe at the side of a main pipe. A lateral sewer has no other sewer discharging into it.
latrine (noun): a pit or enclosure for urination and defaecation
layman (singular noun), **laymen** (plural noun): a person without training in expert professional knowledge
leach, to (verb): to pass through a substance such as earth, usually with water or other liquids
liquid (noun and adj.): a substance, such as water, that can flow easily
loam (noun): earth or soil usually containing clay
lymph (noun): a pale fluid found in the tissue, veins and blood of animals (including man)
lymphatic (adj.)
mains (plural noun): a commonly used term for a main (chief, most important) sewer, also known as a *trunk sewer*, which receives the discharge from the collecting sewage system and takes it to a treatment plant or to the place of final disposal. But note that a main electrical supply or a main water supply is also often called "the mains".
man-hole (noun): an opening large enough for a man to pass through, e.g. in order to inspect, clean or repair an underground sewer
manually (adverb): literally, "by hand": by a person using a tool or tools
material (noun and adj.): the basic stuff or substance making up physical objects
matter (noun): a physical substance; also, pus, a body fluid containing bacteria. See also dictionary.
mature, to (verb): to become fully developed
maturation, maturity (nouns)
mature (adj.)
maximum (adj. and noun): greatest in number, size or quality
mechanize, to (verb): to equip with machinery or with man-made instruments
medium (singular noun), **media** (plural noun): a substance by means of which a required action is produced, e.g. sand for filtering water. See also dictionary.
membrane (noun): a thin sheet of tissue containing very small pores or openings. See also dictionary.
membranous (adj.)
metazoa (plural noun), **metazoon** (singular noun): the zoological group containing all organisms with many cells, and thus including all animals except the protozoa
metazoal, metazoan (adjectives)
micro-organism (noun): a very small living cell. Bacteria, protozoa and viruses are all micro-organisms.
mineralize, to (verb): to change organic matter into inert (inorganic) simpler substances, usually through microbial action. See also dictionary.
minute (adj.) : very small. See also dictionary
molecule (noun): the smallest particle of a substance that has the same chemical form as a mass of the same substance
molecular (adj.)
morbidity (noun): the amount or rate of disease in a community. See also dictionary.
motile (adj.): able to move
mould; U.S. spelling **mold** (noun): a fungus; also, a frame or shape on which or in which an object is constructed
mucus (noun): a sticky fluid produced by glands in the body
mucose, mucous (adjectives)
municipality (adj. and noun): the administrative organization of a town, or the town itself
nematode (noun): a worm shaped like a cylinder, round and long, usually parasitic
night-soil (noun): human faeces and urine. The contents of bucket latrines are called night-soil, because in some countries they are removed from houses at night.
nucleus (noun): the central, essential agent in the growth of most animal and plant cells. See also dictionary.
nuisance (noun): an unpleasant, offensive thing or practice. See also dictionary.
odour, U.S. spelling **odor** (noun): smell
oesophagus, U.S. spelling **esophagus** (noun): the tube leading from the throat to the stomach

offensive (adj.): causing unpleasantness, though not necessarily harmful, to the eyes, nose, ears or mind
offend, to (verb)
offence (noun)
optimum (adj. and noun): most favourable in amount or quality
oral (adj.): taken by mouth. See also dictionary.
organic (adj.): referring to living organisms and their products; composed of substances originating from plants or animals; containing a carbon compound
organism (noun): a living cell or a group or system of cells. A plant, animal and bacterium are all organisms.
pan (noun): a container, a receptacle
parasite (noun): an organism which takes its nourishment from another organism which is its host, either from the host's food or from the host's tissues
parasitic (adj.)
particle (noun): a small part
partition (noun): a structure dividing one part of an area from another. See also dictionary.
pathogen (noun): a cause of disease. See also **bacteria.**
pathogenic (adj.)
pathogenicity (noun): the possibility of or ability for causing disease
per capita (adj. phrase or adverb phrase, Latin): literally "by heads": by person, by unit of population
percolate, to (verb): to trickle or move slowly through a substance
perforate, to (verb): to make a hole or holes in
permeate, to (verb): to spread through, to pass through
pH (initials of noun phrase): potential of hydrogen, usually on a scale 0 to 14, on which 7 represents pure water, 6 to 0 represents increasing acidity, 8 to 14 represents increasing alkalinity
phenomenon (singular noun), **phenomena** (plural noun): a fact or event that can be scientifically explained
photosynthesis (noun): literally, a putting together caused by light: the formation of carbohydrates and hydrogen in plant cells when exposed to light; a release of oxygen caused by light and by chemicals through decomposition in water
pit (noun): a hole, natural or man-made, in the ground. See also dictionary.
plate (noun): a flat piece of metal or other substance
pollute, to (verb): to pass offensive material, fluid or gas into the environment
pollution (noun)
pond (noun): a body of water, formed either by nature or by man
porcelain (noun): a non-porous substance
porous (adj.): full of very small openings, and therefore able to absorb and/or allow the passage of liquid
porosity, porousness (nouns)
potential (adj. and noun): with the power to develop
potentially (adverb)
P.P.M. or p.p.m. (initials of noun phrase): parts per million
prescribe, to (verb): to give directions, to lay down rules. See also dictionary.
privy (noun): literally, "private": a building or construction used for urination and/or defaecation
protein (noun): organic compounds (amino-acids) needed by all living animal and vegetable cells
protozoa (plural noun), **protozoon** (singular noun): the zoological group containing the most primitive, elementary type of organism, usually microscopic, consisting of only one cell
protozoal, protozoan (adjectives)
purify, to (verb): to get rid of dirt or other unwanted material
putrefaction (noun): rotting, decay; breakdown caused by bacteria and fungi
putrefy, to (verb)
quiescent (adj.): motionless, inactive
raw (adj.): in a natural state, not changed by treatment
receptacle (noun): a container
recycle, to (verb): to repeat or to cause to repeat a process or cycle of treatment
reinforce, to (verb): to make stronger with some other materials, e.g. to strengthen concrete with iron rods
remnant (noun): the part remaining after more useful portions have been used or removed
reservoir (noun): a storage place; often a lake where water is collected for use
reservoir of infection (noun phrase): a living organism or inanimate object in which an agent of infection can live and then pass on to a non-resistant host
retain, to (verb): to continue to hold or keep
retention (noun)
Rickettsia (singular and sometimes plural noun): a genus of micro-organisms which live in the cells of the living bodies of arthropods, and which can cause the typhus group of fevers in man
sac (noun): a small bag-shaped or pouch-shaped structure in the body, usually containing air (*air sac*) or fluid. See also dictionary.
sanitary (adj.): in a condition favourable to health
sanitation (noun): the creation of conditions favourable to health

saturate, to (verb): to soak or combine completely with fluid
saturation (noun)
scoop (noun and verb): a large curved spoon-like tool; to use the tool to pick up a substance. See also dictionary.
scum (noun): matter which floats on the surface of a liquid or semi-liquid
seal (noun and verb): a device to stop the escape of gas; to stop access to something. See also dictionary.
secrete, to (verb): to form, to produce, as when living matter forms a material for a specialized purpose. See also dictionary.
secretion (noun)
sediment (noun): the matter that settles down or is deposited at the bottom of a liquid or semi-liquid
sedimentation (noun): the action or process of depositing matter through a fluid
seep, to (verb): to trickle or flow slowly through small openings in a material
seepage (noun)
segment (noun): a part cut off, a section
septic (adj.): putrefying or rotting because of pathogenic bacterial action
septic tank (noun phrase): a large container into which sewage is drained and broken up by the action of anaerobic bacteria
sewage (noun): waste matter, excrement, including liquids. Sewage is often classified as *domestic or sanitary sewage* (from dwelling-places, offices, hospitals, etc.); *industrial sewage* (from chemical plants, factories, tanneries, slaughter-houses, etc.), which usually requires special treatment; and *combined sewage*, which includes domestic or sanitary sewage together with storm water from rainfall, run-off from paved roads and other surface water.
sewerage (noun): the organized removal and disposal of sewage; the drainage system used to remove and dispose of sewage
shallow (adj.): not deep
shed, to (verb): to cast off (Note that the past tense and past participle are also "shed", not "shedded".)
significant (adj.): with meaning and/or importance. See also dictionary.
significance (noun)
signify, to (verb)
silt (noun): earthy material which can be suspended or deposited in liquid
sink (noun): an earthenware or metal basin usually connected with a water supply and drainage. See also dictionary.
sink, to (verb): to go down, to descend; to cause to descend, usually in water
site (noun and verb): place; to place, to put in position
siting (verb-noun): placing in a chosen position
slab (noun): a flat piece of wood, stone or metal
slot (noun and verb): a narrow opening; to provide a narrow opening. See also dictionary.
sludge (noun): the digested or decomposed part of excreta. See also dictionary.
smear, to (verb): to spread with a sticky or oily or dirty material
smear (noun)
soak, to (verb): to make or to become completely wet
soakage (noun): liquid that has seeped through a substance
soil (noun): earth, usually surface earth
soil, to (verb): to make dirty
solar (adj.): from the sun. See also dictionary.
soluble (adj.): able to be dissolved or reduced to a liquid state
solution (noun): a mixture of a substance and a liquid retaining the same physical and chemical properties. See also dictionary.
squat, to (verb): to get into a sitting position, usually without support
squatting-plate (noun phrase): a flat piece of material with a hole in it for defaecation
stabilize, to (verb): to become steady at a constant level, without further change. See also dictionary.
stabilization (noun)
stable (adj.): steady, not likely to change or alter. See also dictionary.
stability (noun)
stagnant (adj.): not moving, not flowing, and therefore unable to purify itself
stagnation (noun)
sterilize, to (verb): to get rid of living micro-organisms from an object. See also dictionary.
stimulate, to (verb): to cause or to increase activity or growth
stool (noun): a discharge of faeces from the body. See also dictionary.
subsoil (noun): the earth under the surface soil
substance (noun): physical or chemical matter or material from which something is made. See also dictionary.
sullage (noun): waste-water or waste material from a kitchen, etc., not usually including human wastes
superstructure (noun): the part of a building above the ground. See also dictionary.
suspend, to (verb): to prevent from falling or sinking, to hold up. See also dictionary.

suspended (verb-adj., passive)
suspension (noun)
symbiosis (noun): the living together of different organisms for their combined benefit
tar paper (noun phrase): heavy paper covered with a thick sticky black substance to make it waterproof
technology (noun): any science which has a practical or economic purpose; applied science
tile (noun): a hollow or open semicircular earthenware or concrete pipe used for draining. See also dictionary.
timber (noun and adj.): wood prepared for use in building, etc.; also, the wood of a growing tree
tissue (noun): the group of cells that form one of the materials composing the body of a plant or animal. See also dictionary.
tolerable (adj.): able to be endured or borne without much difficulty
tolerate, to (verb)
topography (noun): the physical features, natural or man-made, of an area
topographical, topographic (adjectives)
trachea (noun): the main tube through which air passes in and out of the lungs of vertebrates (animals with backbones)
transport, to (verb and noun): to carry from one place to another; a vehicle for carrying material or people. See also dictionary.
trap (noun and verb): a device for preventing the escape of, for example, gas; to stop the escape of. See also dictionary.
trench (noun): a long, usually narrow ditch cut in the ground
trickle, to (verb and noun): to move in very small quantities or drops; a small amount of running fluid
trophozoite (noun): the vegetative or growing form of a protozoon, not resting nor reproducing itself
trunk sewer: see **mains**
turbulence (noun): irregular movement or disturbance
ulceration (noun): the formation of open sores (ulcers) which often contain or discharge infected fluid or pus
urinal (noun): a container for receiving urine; a building designed for urination
urine (noun): waste liquid discharged from the body
urinary (adj.)
urinate, to (verb)
vaccination (noun): the administration of a vaccine
vaccine (noun): literally, from cows: a preparation of living or dead micro-organisms which, when injected into the body, will produce or increase resistance to a particular disease
vacuum (noun and adj.): a space empty of air or other gas or substance, which will therefore fill itself and withdraw matter (e.g. sewage) from a container
vacuum truck (noun phrase): a large lorry or other vehicle equipped with a tank into which sewage can be drawn from a septic tank through a pipe operated by a vacuum pump, and carried away for disposal
vault (noun): a storage compartment, usually with a curved roof or base. See also dictionary.
vector (noun): a carrier of pathogens from one organism to another. See also dictionary.
velocity (noun): speed, quickness
venereal disease (noun phrase): a contagious disease usually passed on by sexual intercourse
vent (noun): an opening for the escape of a gas or liquid. See also dictionary.
vermin (singular and plural noun): small, harmful insects or other animals
vertical (adj.): upward or downward, usually at right angles to a flat surface
viable (adj.): able to live or develop. See also dictionary.
virus (noun): an extremely small micro-organism which is a parasite within a living cell
viral (adj.)
void, to (verb): to discharge from the body. See also dictionary.
volume (noun): amount; also, the measurements or space to be filled. See also dictionary.
vomit, vomitus (noun): stomach contents when ejected through the mouth
vomit, to (verb)
waste, wastes (noun, singular and plural): unwanted substances; excrement. See also dictionary.
water-course (compound noun): a natural or man-made channel for water
waterproof (adj.): coated with a material which will not allow water to pass through
water-seal (compound noun): a method of preventing the escape of gas and smells by keeping a bend in a drain-pipe filled with water
water table (noun phrase): the top limit of ground water, the upper part of an area naturally saturated with water. The water table may be near the surface of the earth, or several metres below it. See also dictionary.
watertight (adj.): constructed so as not to let water pass through
wattle (noun): thin branches or reeds used to weave a protective screen or wall; also acacia trees. See also dictionary.