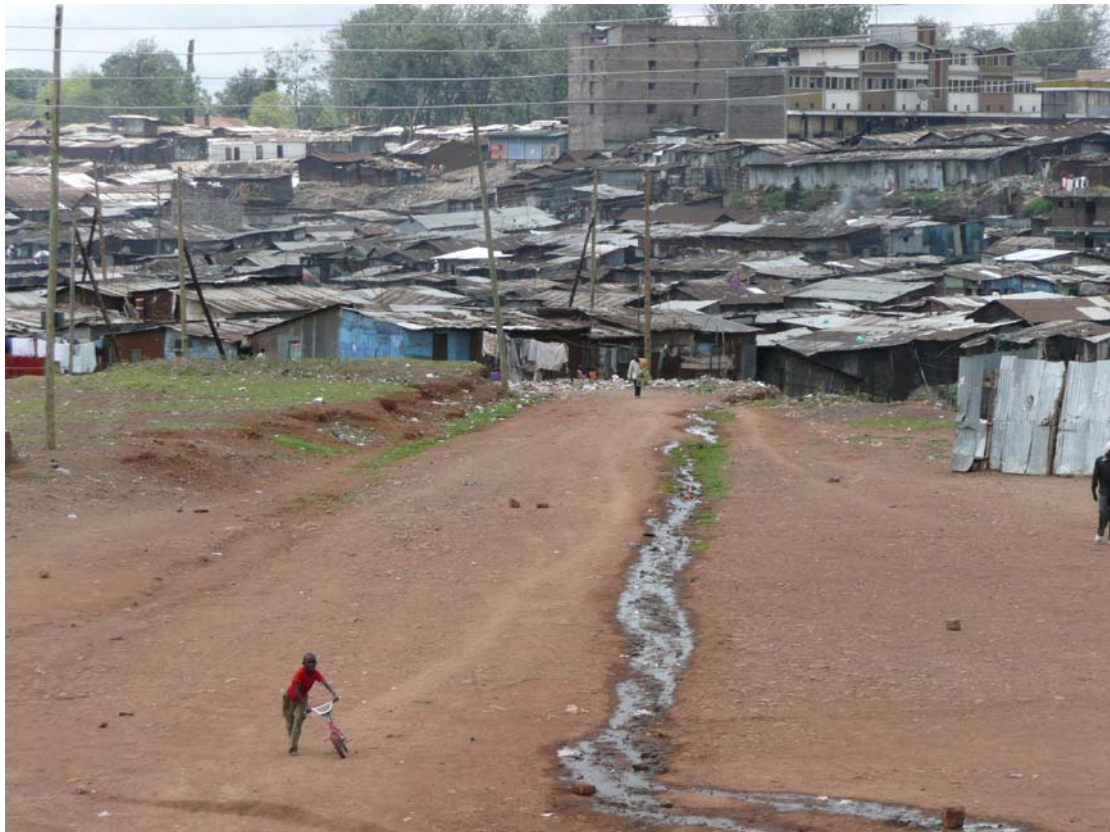


Water Services Trust Fund

Public Sanitation

Liquid Waste Management



Waste water in Mathare, Nairobi

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Financial support for improved access to water and sanitation

Water Services Trust Fund [Urban Projects Concept]

Toolkit for Urban Sanitation Projects

Liquid Waste Management

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Toolkit for Urban Sanitation Projects

Liquid Waste Management

1. Introduction

Sewage may be regarded as waste water and is composed of human body waste (faecal matter and urine) and the sullage from personal washing, laundry, food preparation and the cleaning of kitchen utensils. It may also contain industrial and agricultural waste. Sewage is objectionable in appearance and hazardous in content. Therefore, proper treatment of sewage and safe effluent disposal must be ensured in the management of waste water.

In developing countries, gastrointestinal diseases are associated with ineffective sewage management, rampant poor economies and inadequate sewage treatment plants. Such diseases usually result from discharge of effluents which heavily pollute receiving water bodies. It is very important to treat waste water in such a way that the final effluent will not cause any public health problems.

Fresh sewage is a grey turbid liquid having an earthy but inoffensive odour. It contains large floating solids, small suspended colloidal solids and pollutants in true solution. Sewage may harbour quantities of pathogenic organisms. Depending on the temperature, sewage becomes stale or septic in a very short time.

2. Waste Water Composition

2.1 Composition

Untreated waste water, domestic or industrial, may contain harmful pathogenic organisms or toxic substances which may cause serious health hazards. The strength of sewage is determined by its nuisance potential of offensive odours and biodegradable organic matter. This strength is determined by the oxygen demand (biochemical oxygen demand or BOD) and is measured in milligrams per litre (mg/litre). The higher the BOD, the stronger the sewage is. It is further explained that the lower the dilution, the stronger the sewage; similarly, waste water is considered weak if the dilution is high.

Sewage or waste is composed of human body waste (faeces and urine); sullage from laundry, washing, kitchen waste; and industrial waste. Sewage can be domestic, municipal or industrial.

Waste water must be rendered safe through proper treatment and disposal of the effluent. To be able to carry out such treatment effectively, the characteristics of waste must be known. There are three categories of waste characteristics, namely physical, chemical and biological.

2.2 Physical Characteristics

The physical characteristics of waste water include both suspended and dissolved solids. The suspended solids may be coarse, fine or colloidal in nature and can be removed in preliminary and primary treatment.

Because of the many suspended and dissolved substances, fresh sewage has a soapy grey colour. As it becomes septic, the colour changes to black. Fresh sewage has an insignificant odour, but stale sewage emits a very offensive odour. This is due to biological oxidation which results in depletion of the available dissolved oxygen. The temperature of sewage is slightly higher than that of ordinary water. This is due to bacterial action. Increase in temperature enhances bacterial activity and causes an increase in oxygen utilisation by micro-organisms. Solids in waste water must be identified in order to determine the methods of treatment of waste. Solids may be classified as settleable solids or suspended solids. Settleable solids can be settled and removed through sedimentation. An Imhoff Cone Test is used to determine the amount of solids in waste water. This test determines the amount of settleable solids and necessity of using a sedimentation tank for treatment. It also monitors the efficiency of primary sedimentation by measuring settleable solids of influent and effluent.

A percent-reduced BOD

Approximately 35-40 per cent of domestic waste water treatment may be achieved through sedimentation of settleable solids. Suspended solids (colloids), on the other hand, are not in solution and are not readily settleable. They will always remain in suspension.

2.3 Chemicals Characteristics

Chemical matter is organic or inorganic. Organic matter is composed of proteins, carbohydrates, urea and grease. While inorganic matter consists of salts, grit and metals. Fresh sewage is alkaline in nature and enhances bacterial action; on the other hand, stale or Septic sewage is acidic and difficult to treat. High chemical content may interfere with water treatment.

3. Chemicals in Waste Water

Waste water contains numerous chemicals. The composition and nature vary depending on whether the waste water is domestic or industrial. Organic nitrogen occurs mainly as protein and urea as nitrogen is present in faeces and urine. Raw sewage may contain 20-50g/litre of organic nitrogen.

Ammonia nitrogen is nitrogen occurring as ammonia dissolved in water. A typical content of sewage is 10-30mg/litre. Brewery and beverage waste is deficient in organic matter. Thus, it may be necessary to supplement it with ammonia nitrogen for satisfactory aerobic action. Nitrite nitrogen is the incomplete stage of oxidation of nitrogenous matter to mineralisation. It is found in the effluents from waste water treatment. This chemical is formed by ammonia nitrogen combining with oxygen to give nitrite and nitric combining with oxygen to give nitrate. The presence of nitrate nitrogen in waste water indicates old pollution. It is a stable oxidation product and occurs in large quantities in many sewage effluents. It has a high oxygen demand: oxidation of 1 mg of ammonia nitrogen to nitrate nitrogen requires 4.5 mg of oxygen.

Nitrate may lead to disease called methaemoglobinaemia (or “blue baby disease”), which is a reduction of oxygen in the bloodstream of babies.

Phosphorous may be dissolved by rainwater as it percolates through soil rich in phosphorous and nitrate fertilisers. In sewage and industrial waste, phosphates are introduced from excess foods, industrial discharges and synthetic detergents. Excess phosphorous encourages eutrophication in receiving streams. This phenomenon occurs when water bodies have been enriched with nutrients which encourage the growth of aquatic vegetation. Phosphorus is the limiting nutrient in fresh water.

Sulphur is found in most natural waters. It occurs in the industrial discharge from distilleries, metal finishing factories, tanneries and paper/ pulp industries where it is used in large quantities. It acts as a coagulant in water treatment. Sulphur may be used as a disinfectant. Ammonia sulphate can be used as an algicide for control of algal growth. Paints having this compound can be used for painting the inside of storage tanks to prevent algal growth.

The reduction of sulphate to sulphide can interfere with the fabric of sewage. Biological changes are constantly occurring in sewage during transportation to treatment works. These changes require oxygen, and if it is not available in the sewer, sulphates are reduced to sulphide.

At the usual pH level of domestic waste water, most of the sulphate is converted to hydrogen sulphide, a poisonous gas, some of which escapes to the sewer atmosphere above the waste water. If the sewer is well-ventilated, it does no damage, but in poorly-ventilated sewers, moisture collects on the walls and crown of the sewer. Hydrogen sulphide dissolves in this water, and some of the drops may fall in the sewage when heavy. The hydrogen sulphide itself may not cause any harm at all, but because of the anaerobic conditions normally prevailing in sewers, the bacteria therein are capable of oxidising it to sulphuric acid or hydrogen sulphite. This is a strong acid which attacks sewer fabric and is particularly serious at the crown where drainage is minimal. Hydrogen sulphide is a poisonous gas which paralyses the sense of smell and has anaesthetic effects. It is therefore necessary, when unblocking sewers, to open the entrance slowly and wait for the gas to escape and fresh air to enter. Sulphates may also increase corrosion of treatment units.

4. Biological Characteristics

All organic matter contains large numbers of micro-organisms. Those found in waste water include bacteria, algae, fungi and protozoa. Bacteria are the most active and are present in large numbers in sewage. For example, 4.5 litres of sewage may contain 20-25 billion bacteria. Coli forms, the organisms that inhabit the human intestinal tract, act as indicator organisms in water analysis. Presence of coli forms in a water sample indicates faecal contamination.

Stabilisation of organic matter is achieved by the reaction of bacteria and other micro-organisms reaction in the presence of oxygen. The BOD of waste water is the measure of the concentration of organic compounds present in the waste expressed in terms of the oxygen required for their bio-oxidation. The BOD of waste water is a measure of the concentration of the organic compounds present in the waste expressed in terms of the oxygen required at a constant temperature of 20 degrees Celsius. Oxidation (or catabolism) is the breaking down of organic matter to relatively simpler end products with emission of energy. Synthesis (or anabolism) occurs when

micro-organisms use the energy released through oxidation to grow and multiply. These two reactions take place concurrently.

There are three types of bacteria, and their function depends on environment and exposure. There are two types of beneficial bacteria; they assist in the stabilisation of organic matter. PROTOTROPIC bacteria obtain their food from mineral compounds such as nitrates and carbonates in sewage. METATROPHIC bacteria are very important and obtain their food from organic compounds such as nitrogenous and carbonaceous matter. These can be further sub-classified as aerobic, anaerobic and facultative bacteria.

5. Wastewater Treatment

Untreated sewage is dangerous to public health because it contributes to environmental water, land and air pollution. This facilitates transmission of disease, depreciation of land and degradation of the environment. The waste must be thoroughly treated to produce an effluent that is safe and environmentally acceptable and which is finally conveyed to disposal sites.

The fundamental equation for waste water treatment is:

Organic waste + oxygen + bacteria = Treated waste = New bacterial cells

1. Discharging highly polluting waste into a body of water has negative effects on human, animal and plant life. There is a reduction of dissolved oxygen which may affect aquatic life; at the same time, the absence of dissolved oxygen in the water leads to septic conditions. Health hazards to communities are increased and social amenities such as swimming are decreased. Too many pollutants reduce the self-purification capacity of water, especially at the point of mixing, and they promote excessive growth of aquatic plants. Polluted waters are aesthetically objectionable because they emit unpleasant odours.

Waste water should be treated to:

1. Reduce environmental pollution, e.g., receiving water bodies and land.
2. Reduce costs of treatment of water supplies.
3. Render obnoxious materials, e.g., sludge, harmless.
4. Conform to any river standard in terms of suspended solids and BOD, i.e., to comply with official, designated standards.
5. Allow for recovery of useful by-products e.g., effluent for irrigation or dry sludge as fertilisers.
6. Kill pathogenic organisms.
7. Avoid nuisance.

The theory of sewage treatment plants is that micro-organisms will metabolise the available organic matter. The design is to provide an apparatus or environmental conditions in which this action will take place as quickly, economically as possible. Waste water treatment, therefore, should prevent pollution of water by matter,

inorganic matter and toxic substances. It should further nuisances and minimise health hazards in the environment. Treatment should produce an effluent that is suitable for its intended re-use and will not constitute a risk to public health. To achieve its aim, waste water treatment must produce an effluent of certain quality or standard. The relevant authority should establish the required effluent quality.

Effluent for	BOD mg/litre	Faecal coliform/100 ml	Algae/ml
Discharge to surface water	>25	>500	>100,000
Restricted irrigation	-	>500	
Unrestricted irrigation	-	>500	

Knowledge of the nature of the waste water you intend to treat is very important!

Waste varies in its characteristics. It is important to know the quantity of waste water to be treated as well as the BOD load, suspended solids content and settleable solids content of the sewage. Waste water can be treated aerobically available. There are three types of bacteria commonly used:

1. Aerobic bacteria - Those which only function in an environment where there is free oxygen or dissolved oxygen.
2. Anaerobic bacteria - Those which function well in an environment where there is combined oxygen, not dissolved oxygen.
3. Facultative bacteria - Those which can exist in both aerobic and anaerobic conditions.

All three types of bacteria may be present within a given treatment plant.

6. Methods of Treatment

6.1 Introduction

Sewage may be treated using any of the three bacteria with a wide range of success. The success of each is dependent on a number of factors such as the target population, the amount of water being used, the availability of land, availability of receiving bodies and, to a lesser extent, the climatic conditions. Widely used treatment works include waste stabilisation ponds, trickling filters, aerated lagoons, oxidation ditches with activated sludge process and septic tanks.

The method of waste water treatment to be adopted depends on a number of factors. Cost is a main factor; hence it is necessary to choose a method which requires minimum running costs. There should be little nuisance from flies or odours. Adequate land and porous soil should be available. Degree of treatment and purpose of final products should be considered. Another factor is the quantity of flow which is influenced by population density. Also, each type of waste (industrial, domestic or municipal) has its own characteristics. Other factors include means of effluent disposal, climate and preference of individual engineer.

6.2 Conventional Stages in Sewages Treatment

Treatment of waste water takes place in four stages

1. Preliminary treatment.
2. Primary treatment (sedimentation).
3. Secondary treatment.
4. Tertiary treatment.

6.3 Preliminary Treatment

6.3.1 Main Objectives

The main aim in preliminary treatment is to protect the treatment works. This involves the removal of material such as grease and grit which may be adversely interfere with the waste water treatment.

In preliminary treatment the sewer load can carry six times the dry weather flow (DWF). Three times the DWF should be stored in overflow tanks; it can be brought back to the system or disposed of after a detention time of 1day. Excess (three DWF) of low strength sewage can be discharged into a river; however this should be avoided. There should be a screen to hold back a large particles entering the system. The grit is removed before sedimentation. A communitor is used for breaking down large particles that might have gone through the screens.

6.3.2 Screens

Screens are essential for the removal of large solids. Two types of screens are used in treatment plants: hand rake screen sand mechanical rakes. For flows less than 200 cubic in per day, the hand rake screen is inclined at 30 to 60 degrees to the horizontal. The level of the waste water is lower after the screening due to head loss caused by trapped screenings. These are removed manually with hand rakes and must be properly disposed of in tertiary treatment. Mechanical rakes present a concave face to the flow of waste water. Screenings are discharged into the trough and are later carried away for disposal. The velocity through the bars should be 0.6-1ml/s. Higher velocity might force some large screenings through the bars. The bar spacing is normally 10-40mm. Screening are disposed of either by drying followed by burning or by burying (tertiary treatment), these are rich in organic matter and therefore should be handled with care.

A macerator is used to cut screenings into smaller pieces; where desirable, the cut screenings can be passed together with waste water or disposed of.

6.3.3 Grit Chambers

Grit chambers are for removal of sand, gravel and similar debris. Grit chambers are provided to protect moving equipment from abrasion and wear; they are located immediately after screens. The chambers are shallow, elongated channels that allow settlement of particles with specific gravity of 2.65 or more. Mechanical rakes can assist in the removal of grit that accumulates before the screen.

A flume is necessary for the measurement of daily flows. DWF is defined as the average daily flow rate of waste on days when not more than 2.5mm of rain has

fallen in the previous 24 hours. The DWF is often equal to the water consumption minus the evaporation plus the infiltration or minus the exfiltration (leakage outwards). Infiltration may contribute up to 30 per cent of DWF.

6.3.4 Grease in Waste Water

Domestic and industrial sources are the chief contributors of grease in waste water. Domestic examples include human faeces, kitchen waste and laundry waste. Industrial sources include slaughter houses, tanneries, oil refineries, soap factories and garages.

Grease removal from waste water is very important as it prevents oil "slick" which is a formation of an oil cover the waste water. Oil slick is unsightly and may interfere with aquatic life. It will not allow entry of atmospheric oxygen into the waste water. It may also cause coating of various components in sag treatment plants. In piping, grease causes reduction of diameters through coating, especially on bends. However, this depends on the amount of grease. Grease may cause coating of distributor and filter media in trickling filters. Clogging of air diffusers may occur with artificial aeration in lagoons. In receiving water bodies, grease causes oil slick which in turn affects aquatic life because it prevents aeration of water by atmospheric air.

The presence of grease can deter effective waste water treatment. Therefore, its removal is vital. Grease in waste water can be removed in two ways, namely, flotation or electrolysis. In flotation, air is introduced into the waste water at very high pressure. Gas bubbles attach themselves to oil particles which rise to the top (buoyancy) forming scum. The scum is then removed manually or mechanically. With the use of electrolysis, bubbles of gas are generated between positive and negative electrodes. Reduction of the apparent specific gravity of oil particles by attachment of gas bubbles occurs, and this causes the oil particles to rise to the top. The scum is then manually or mechanically removed.

6.4 Primary Treatment (Sedimentation)

Sedimentation follows immediately after preliminary treatment and it uses the same basic principles. The chief aim is to remove settleable solids in waste water. To determine whether a sedimentation tank is necessary, a test is carried out using Imhoff cones. In the case of domestic waste water, there is removal of about 60-70 per cent of the settleable solids. BOD removal can be between 30 and 40 per cent. Generally, primary sedimentation is economical and efficient for the removal of solids.

$$\begin{aligned} \text{BOD of raw waste water} &= 300 \text{ mg/litre} \\ \text{BOD 40 per cent removal} &= (40 * 300)/100 = 120 \text{ mg/litre} \end{aligned}$$

Therefore, the effluent will have a BOD of 180 mg/ litre
 Influent - BOD 40 per cent - Effluent 180 mg/ litre
 300 mg/ litre sedimentation tank

6.5 Secondary Treatment

Secondary treatment is mainly biological treatment. If free oxygen is available, aerobic reaction will take place in the presence of aerobic bacteria. In the absence of

free oxygen, anaerobic reaction occurs with anaerobic bacteria. The facultative bacteria may then function in both aerobic and anaerobic environments.

In aerobic biological treatment (ABT), the combination of organic matter, dissolved oxygen and micro-organisms gives rise to oxidation and synthesis. Therefore, the objective of ABT involves the removal of oxygen-consuming organic matter from waste water. The reduction, oxidation or stabilisation of organic matter present is represented by BOD. The amount of the organic matter present is represented by BOD. The micro-organisms will use molecular (free) oxygen during biochemical oxidation.

Organic matter + micro- organisms + bacteria= Simple end products + new bacterial cells

Various conditions are necessary for efficient treatment. The dissolved oxygen content should always be greater than 1 mg/ litre. The pH should be maintained within the range of 6.5-8.5. Nutrients such as nitrates and phosphates must be present. Toxic compounds must be below problematic levels, and the waste must be readily biodegradable. The rate of oxygen uptake by organic matter should be less than the oxygen transfer from the atmosphere. Temperature is difficult to control, but it is not a problem in the tropics.

6.6 Waste Stabilisation Ponds

Lagoons, oxidation ponds and stabilisation ponds are the same thing. The system does not need any extra attention apart from maintenance. The general terms *lagoon* and *stabilisation pond* are used to describe shallow, constructed lakes which may be designed to treat organic waste water using a “once through” mode of operation; that is, nothing is returned.

Influent → Lagoon → Effluent

They are rectangular in shape and 1 to 1.5 m deep, although the depth can sometimes be more. They are useful for the treatment of waste from large communities. Oxidation ponds are widely used in hot climates. Lagoons are like human-made lakes and occupy large areas of land. They are therefore more ideal in localities where land is not a problem.

Features of waste stabilisation ponds:

- Trapezoidal shape.
- Between 1 and 4 m deep.
- Sloping sides.
- Inlet/outlet structures.
- Concrete slab linings on the sides.
- Rectangular embankment large enough to facilitate vehicle access.

They are three main types. In anaerobic ponds, conditions of treatment are strictly anaerobic and are associated with high BOD load. They act as sludge deposit chambers. In facultative ponds, both aerobic and anaerobic reactions exist. The upper layers are aerobic while the bottom layers are anaerobic. The function of maturation ponds is strictly the destruction of faecal pathogens, ova and cysts. Conditions are purely aerobic.

Symbiosis occurs chiefly in facultative ponds. During the hours of darkness, the entire environment in the pond may become anaerobic. This is because photosynthesis takes place in the presence of sunlight. The algae in the presence of sunlight produce oxygen which is used by bacteria to oxidise organic matter. Bacteria give out carbon dioxide and other nutrients necessary for algal; hence, there are mutual benefits for both.

6.7 Trickling Filters

When using a trickling filter, primary sedimentation is necessary as a pre-treatment to remove solids. A reasonably uniform application of waste water (intermittent) over the media is necessary for effective treatment. Correct media size and shape are necessary. If media are too small, the filter may get blocked easily. The normal size varies from 25 mm to 100 mm. The filter should have a good under-drain for complete effluent removal. This ensures proper ventilation and provides support for the media. There should be ecological balance as well as balance of micro-organisms. The design should facilitate proper hydraulic or organic loading.

There should be no difficulty in starting the operation of a well constructed trickling filter other than the time lag required to build up (develop) an active film of micro-organisms will establish itself in a few weeks. Industrial waste is not always capable of forming the necessary biological growth, and it is common practice to start industrial waste filtering with sewage or a sewage product such as septic tank effluent. Once a trickling filter is in operation, waste flow to the filter should not be discontinued because even a few hours of inactivity will reduce the biological efficiency, and biomass may decrease.

Clogging is a condition of local flooding within the filter bed .It occurs when liquid is unable to pass through the bed. At the top surface, it appears as a pond between dosing. Within the filter, clogging is less obvious. In other locations, it interferes with filter operation since passage of air (oxygen) through the clogged region is retarded and anaerobic conditions may develop. Effluent qualities under such conditions may be considerably impaired.

Clogging may be caused by too fine a stone size (media) in the bed, or it may be from too wide a range of stone sizes since this result in a closer parking which increases free area of liquid movement. Clogging may occur because of the nature of the waste For example, excessive quantities of suspended solids in the waste water fed to the filter causes overloading and building up of deposits on or within the bed. In case there is clogging, rest the unit for a few days to dry the flock and slough off. When waste water is passed through again, it washes already sloughed materials.

Small grey flies are very prevalent around tricking filters; they are referred as “filter flies “. They are a nuisance because of their large numbers. Chlorinating the waste entering the filter may keep the flies under control. Also overdosing with chlorine may kill some other micro-organisms. Since the whole action of the trickling filter is based on biological growth, any toxic materials that affect health and activity of micro-organisms will impair the efficiency of the filter temporarily or permanently. In municipal sewage treatment, strict limitations on discharge of toxic waste into sewers are needed in order to prevent disturbances of the treatment process. A reasonable degree of toxic materials can be developed in the filter biomass by gradual build-up of toxic concentration, but shock loads or sudden surges of concentrated poison are often disastrous to filter efficiency.

6.8 Septic Tanks

Septic tanks are small rectangular chambers that are normally sited just below the ground level ; they receive both excreta and flush water from household toilets . The mean hydraulic retention time (HRT) in the tank is usually 1 to 3 days. During this time the solids settle to the bottom of the tank where they are digested anaerobically and a thick layer of scum is formed at the surface. Although the deposition of the settled solids is reasonably effective, some sludge accumulates. Thus, the tank must be desludged at regular intervals - one every 10 to 15 yrs. However, this depends on design and the number of users. The effluent from septic tanks is dangerous and should therefore be treated. It may be discharged to soakage pits or leaching fields. It should not be discharged to surface drains or water courses without further treatment.

A two- compartment septic tank is now generally preferred to one with a single compartment. This is because the suspended solids concentration in the effluent is considerably lower. The first compartment is usually twice the size of the second; the liquid depth is 1 to 2 m and the overall liquid to the breath ratio is 3: 1. Experience has shown that in order to provide for sufficiently quiescent conditions for effective sedimentation of sewage solids the liquid retention time should be at least 24 hrs.

Two thirds of the tank volume is normally reserved for storage of accumulated sludge and scum so that the size of the septic tank should be based on three days retention at start up. Sludge accumulates at the rate of 0.03 to 0.04 cubic m per year.

Thus, knowing the number of users, the interval between successive de-sludging operations is when it is one-third full of operation. The septic tank should be watertight such that there is no movement of water into or from the tank.

N/B The rate of sludge accumulation is temperature dependent.

A septic tank is recommended and appropriate where there is an in-house water supply and sufficient land for effluent disposal. When water supply is inadequate, drainage pipes will not be maintained and decomposition of faeces will take place therein. Frequent flushing is necessary. Soil permeability must be good for effluent disposal. There should be ample space for percolation and drainage.

Septic tanks can be upgraded to a water-borne system and thus joined to a main sewerage system later. Septic tank effluent can be discharged by soakaway pits, drain fields or oxidation ponds. Soakaway pits are dug to receive effluents from septic tanks or kitchens .They should be used only in pervious soil and above the water table. The pit volume should be enough to accommodate the effluent from the installation served. Pits are commonly 1 to 2.5 m in diameter and 2 to 3 m deep this can be built into series.

This is a system which is usually adopted in isolated plots or areas not covered by sewerage system.

6.9 Sludge treatment and Disposal

Sludge may be treated or disposed of through any of the following methods:

- Digestion.

- Aerated sludge process.
- Drying/incineration.
- Burying.
- Discharging into existing sewage works.
- Recycle to fertiliser.¹

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¹ When human faecal matters are recycled as fertiliser and being used in farms for crop production soil, fertiliser, crops e.g. should be monitored by constant sampling to check helminthiasis organisms responsible for helminthic diseases e.g. cestodes, flatworms, trematodes, etc.