CHAPTER 2

WASTE WATER TREATMENT

2.1 This chapter is concerned with liquid wastes as found at permanent locations. Although field-type wastes are mentioned in this chapter, they are discussed in more detail in part 2. Australian Defence Force health staff should coordinate with the appropriate overseas or domestic health authorities to ensure compliance with applicable health and environmental regulations.

2.2 The wastewater discussed in this section is predominantly of domestic origin. Varying amounts of industrial and laboratory wastewaters can be collected and treated with the sanitary sewage. The primary purpose of the treatment of sewage is to prevent the pollution of the receiving waters. Many techniques have been devised to accomplish this aim for both small and large quantities of sewage.

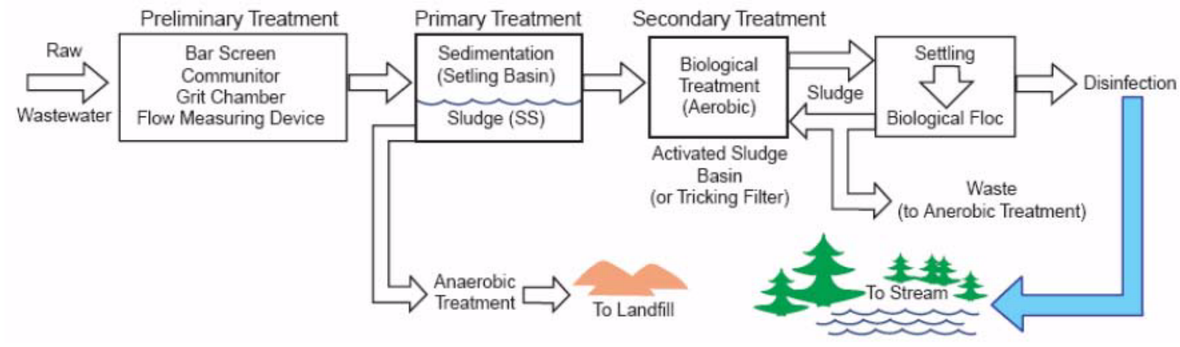

Figure 2–1: Schematic of a typical wastewater treatment plant

2.3 In general, these processes are divided into three stages: preliminary (physical), primary (physical) treatment and secondary (biological) treatment. Figure 2–1 provides a schematic of a typical wastewater treatment plant. Minimally, wastewater should receive primary (physical removal/settling) and secondary (biological) treatment, which can be followed by disinfection before discharge. More advanced processes (advanced or tertiary treatment) may be required for special wastes. When the effluent from secondary treatment is unacceptable, a third level of treatment, tertiary treatment, can be employed. There are many basic types of sewage treatment plants employing both primary and secondary treatment stages that are in use today for treating large quantities of sewage.

COLLECTION SYSTEM

2.4 The purpose of a sewage collection system is to remove wastewater from points of origin to a treatment facility or place of disposal. The collection system consists of the sewers (pipes and conduits) and plumbing necessary to convey sewage from the point(s) of origin to the treatment system or place of disposal. It is necessary that the collection system be designed so that the sewage will reach the treatment system as soon as possible after entering the sewer. If the length of time in the sewers is too long, the sewage will be anaerobic when it reaches the treatment facilities.

2.5 Sanitary sewage collection systems should be designed to remove domestic sewage only. Surface drainage is excluded to avoid constructing large sewers and treating large volumes of sewage diluted by rainwater during storms. Sewers which exclude surface drainage are called sanitary sewers, and those which collect surface drainage in combination with sanitary sewage are called combined sewers.

2.6 Except for force mains, sewers are laid to permit gravity flow of their contents. Unlike water in a water distribution system, the contents of a sewer do not flow under pressure. Usually the slope is such that a flow rate of 0.03 metre (m) per second or more is maintained when the line is flowing half full to full. This is a self-cleansing velocity and prevents solids from settling in the sewer pipes. To the maximum extent practical, sewers are laid in straight lines. Corners and sharp bends slow the flow rate, permit clogging, and make line cleaning difficult.

2.7 Pumping is necessary where the slope of the sewer does not produce the required minimum velocity of 0.03 m or where sewage must be lifted to a higher elevation. Sewage can be pumped from pumping stations through pressure lines (force mains) regardless of their slope, or it can be raised to a higher elevation at pumping stations (lift stations), so that gravity flow will again produce the required velocity.

2.8 For gravity flow lines, sewer pipes of vitrified clay tile, concrete, cement-asbestos, or bituminous-impregnated fibre may be used. For force mains and stream crossings, cast iron or cement-asbestos pipes are used.

2.9 Removing grease from sewage is essential to the proper functioning of sewage systems. At fixed installations, grease is collected by ceramic or cast iron grease interceptors installed at kitchens and other facilities that generate grease and by concrete or brick grease traps outside the building. Approximately 90 per cent of the grease will be removed from greasy wastes by properly maintained grease interceptors and traps.

2.10 Petrol and oil separators are installed in sewer lines from garages and shops where petrol and oil might be accidentally spilled. Separators are also installed under washing facilities to contain the oil in water. In areas where large amounts of volatile material are produced as waste, some other method must be provided. Volatile liquids accumulating in sewers can cause explosions and destroy sewer lines or the treatment plant.

WASTEWATER MANAGEMENT TRICKLING FILTER SYSTEM

2.11 A common type of treatment system used at military installations where extensive water collection systems handle large quantities of sewage is the trickling filter system (*see* figure 2–2). The trickling filter system employs the following units:

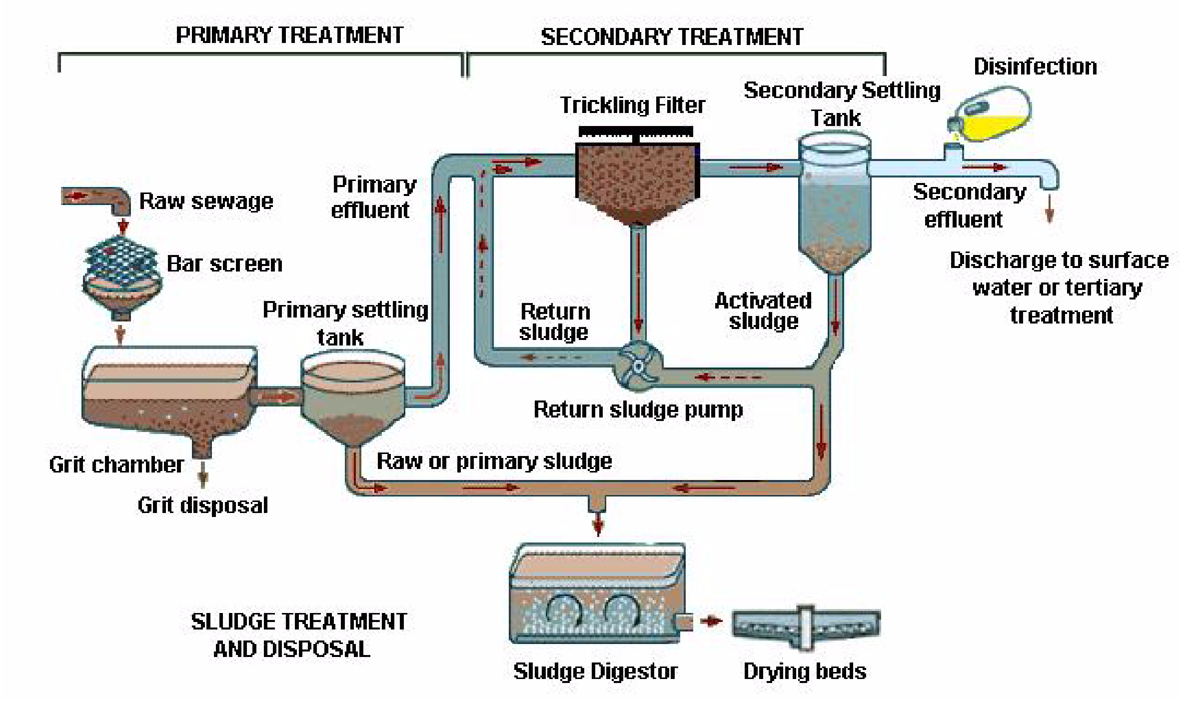

Figure 2–2: Wastewater treatment based on a trickling filter system

Bar screens

2.12 A grating of steel bars spaced about 2–4 cm on centres is placed at an angle to the flow of sewage through an open channel (*see* figure 2–3). The raw influent first goes through a self-cleaning screen and then into one end of a shallow and rather fast moving basin so that sand and gravel can settle out. Often skimmers rotate around the surface of the basin to remove oils that may have been flushed into the system. The screen removes coarse and floating solids from the sewage. The screen must be cleaned regularly and the removed solids must be burned, ground and digested, or buried. Many systems have a grinder known as a comminutor used either with or instead of a bar screen for grinding large particles which might clog the pumps.

Figure 2–3: Bar screen

Grit chamber

2.13 A chamber in which the velocity of waste flow is reduced to a point where the denser sand and other grit will settle out, but the organic solids will remain in suspension (refer figure 2–4). The settled material is buried or used for fill.

Figure 2–4: Grit chamber

Primary settling tanks (or basins)

2.14 These are usually large tanks in which solids settle out of water by gravity (refer figure 2–5 and 2–6) where the settle-able solids are pumped away (as sludge), while oils float to the top and are skimmed off. It operates by means of the velocity of flow is reduced to about 0.005 m so that the suspended material (organic settleable solids) will settle out. The usual detention time is 11/2–21/2 hours. Longer periods usually result in depletion of dissolved oxygen and subsequent anaerobic conditions. Removal of suspended solids ranges from 50–65 per cent, and a 30–40 per cent reduction of the five-day biochemical oxygen demand (BOD) can be expected. For more information on BOD, *see* paragraph 2.48.

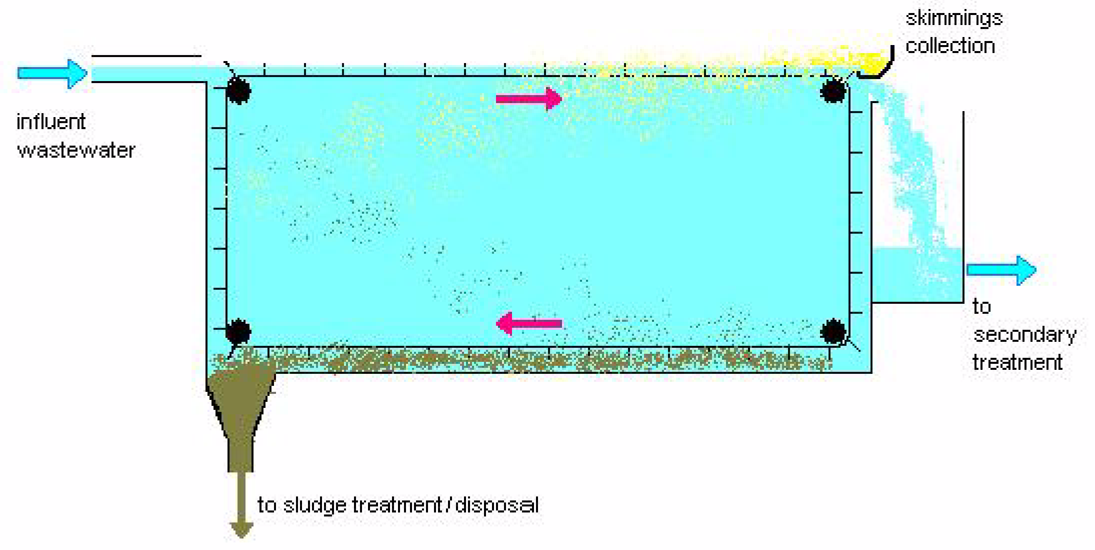

Figure 2–5: Primary settling tank schematic

Figure 2–6: Primary settling tank

Sludge digestors

2.15 The sludge which settles in the sedimentation basin is pumped to the sludge digestors (*see* figure 2–7) where a temperature of 30–35ºC is maintained. This is the optimum temperature for the anaerobic bacteria (bacteria that live in an environment that does not contain oxygen). The usual length of digestion is 20–30 days but can be much longer during winter months. Continual adding of raw sludge is necessary and only well-digested sludge should be withdrawn, leaving some ripe sludge in the digestor to acclimatise the incoming raw sludge.

Figure 2–7: Sludge digestors

Drying beds

2.16 Digested sludge is placed on drying beds of sand (*see* figure 2–8) where the liquid may evaporate or drain into the soil. The dried sludge is a porous humus-like cake which can be used as a fertiliser base.

Figure 2–8: Drying beds

Trickling filters

2.17 The liquid effluent from the primary settling tank is passed to the secondary part of the system where aerobic decomposition completes the stabilisation. For this purpose, a trickling filter (*see* figures 2–9 and 2–10) is used.

2.18 A trickling filter is a fixed bed, biological filter that operates under (mostly) aerobic conditions. Pre-settled wastewater is 'trickled' or sprayed over the filter. As the water migrates through the pores of the filter, organics are degraded by the biomass covering the filter material.

2.19 The Trickling Filter is filled with a high specific surface-area material such as rocks, gravel, shredded PVC bottles, or special pre-formed filter-material. A material with a specific surface area between 30 and 900m^2/m^3 is desirable. The filter is usually 1–3 m deep but filters packed with lighter plastic filling can be up to 12 m deep. Pre-treatment is essential to prevent clogging and to ensure efficient treatment. The pre-treated wastewater is 'trickled' over the surface of the filter. Organisms that grow in a thin bio-film over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water while generating new biomass.

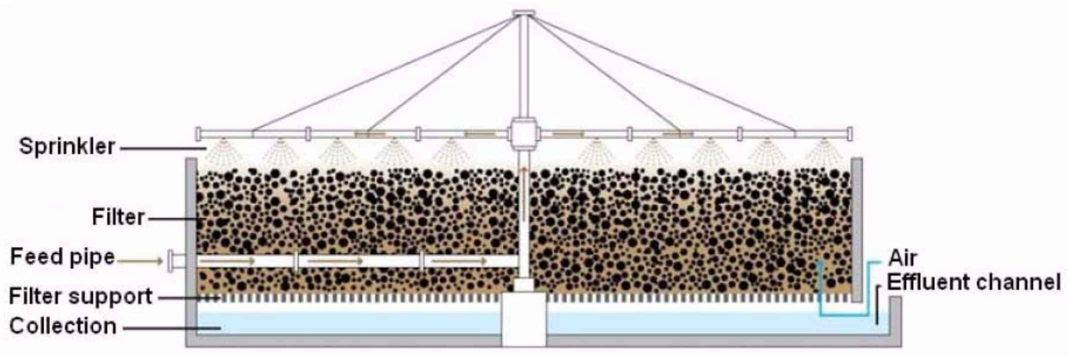

Figure 2–9: Trickling filter

2.20 The incoming wastewater is sprayed over the filter with the use of a rotating sprinkler. In this way, the filter media goes through cycles of being dosed and exposed to air. However, oxygen is depleted within the biomass and the inner layers may be anoxic or anaerobic.

Figure 2–10: Trickling filter

2.21 The ideal filter material has a high surface to volume ratio, is light, durable and allows air to circulate. Whenever it is available, crushed rock or gravel is the cheapest option. The particles should be uniform such that 95 per cent of the particles have a diameter between seven and 10 cm. Both ends of the filter are ventilated to allow oxygen to travel the length of the filter. A perforated slab that allows the effluent and excess sludge to be collected supports the bottom of the filter.

2.22 The bed consists of crushed rock or slag (1–2 m deep) through which the sewage is allowed to percolate. The stones become coated with a zoogloea film (a jelly-like growth of bacteria, fungi, algae, and protozoa), and air circulates by convection currents through the bed. Most of the biological action takes place in the upper 0.5 m of the bed. Depending on the rate of flow and other factors, the slime will slough off the rocks at periodic intervals or continuously, whenever it becomes too thick to be retained on the stones. A secondary settling basin is necessary to clarify the effluent from the trickling filter. The overall reduction of BOD for a complete trickling filter system averages around 80–90 per cent.

Secondary settling tank

2.23 With the majority of the suspended material removed from the sewage, the liquid portion flows over a weir at the surface of the secondary settling tank (*see* figure 2–11). Chlorination of the effluent from the secondary settling tank takes place in accordance with state and local laws. Depending on the location most laws require that a free available chlorine (FAC) residual (usually 0.2 mg/L) be maintained after a 30-minute contact period. This contact period is obtained through the use of chlorine contact chambers which are designed to provide a 30-minute detention time. From the chlorine contact chamber the treated sewage is normally discharged into a receiving body of water.

Figure 2–11: Secondary settling tank

Activated sludge system

2.24 Activated Sludge is a multi-chamber reactor unit that makes use of (mostly) aerobic microorganisms to degrade organics in wastewater and to produce a high-quality effluent. To maintain aerobic conditions and to the keep the active biomass suspended, a constant and well-timed supply of oxygen is required. Activated sludge systems (refer figures 2–12 and 2–13) normally make use of bar screens and/or comminutors, grit chambers, primary settling tanks, secondary settling tanks, and digesters, which are operated in the same manner as those of trickling filter systems. They differ from the trickling filter systems in that they make use of an aeration tank instead of a trickling filter.

2.25 Different configurations of the Activated Sludge process can be employed to ensure that the wastewater is mixed and aerated (with either air or pure oxygen) in an aeration tank. The microorganisms oxidize the organic carbon in the wastewater to produce new cells, carbon dioxide and water. Although aerobic bacteria are the most common organisms, aerobic, anaerobic, and/or nitrifying bacteria along with higher organisms can be present. The exact composition depends on the reactor design, environment, and wastewater characteristics. During aeration and mixing, the bacteria form small clusters, or flocs. When the aeration stops, the mixture is transferred to a secondary clarifier where the flocs are allowed to settle out and the effluent moves on for further treatment or discharge. The sludge is then recycled back to the aeration tank, where the process is repeated.

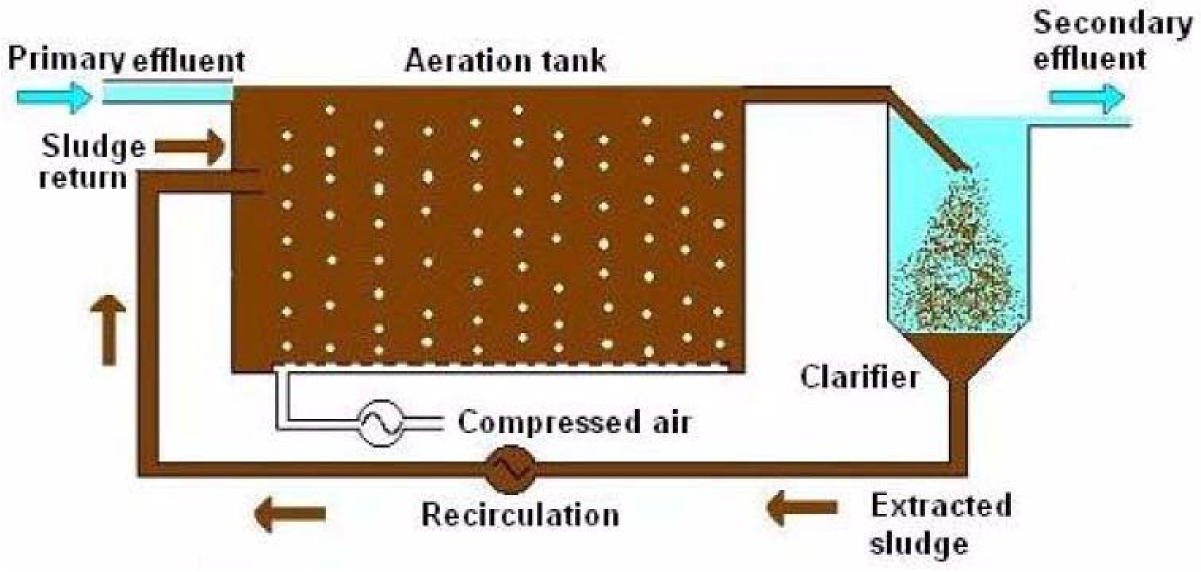

Figure 2–12: Activated sludge system example one

2.26 Compressed air is continually diffused into the sewage as it flows through the aeration tank. This provides both a source of oxygen for the aerobic bacterial floc that forms in the tank and the turbulence necessary to bring the waste and the bacteria into contact. Aerobic bacteria attack the dissolved and finely divided suspended solids not removed by primary sedimentation. Some of the floc is removed with the sewage that flows out of the aeration tank and carried into the secondary settling tank. Here the floc settles to the bottom of the tank, and is later pumped back into the aeration tank. The liquid portion then flows over a weir at the surface of the settling tank to be chlorinated and released to a receiving stream.

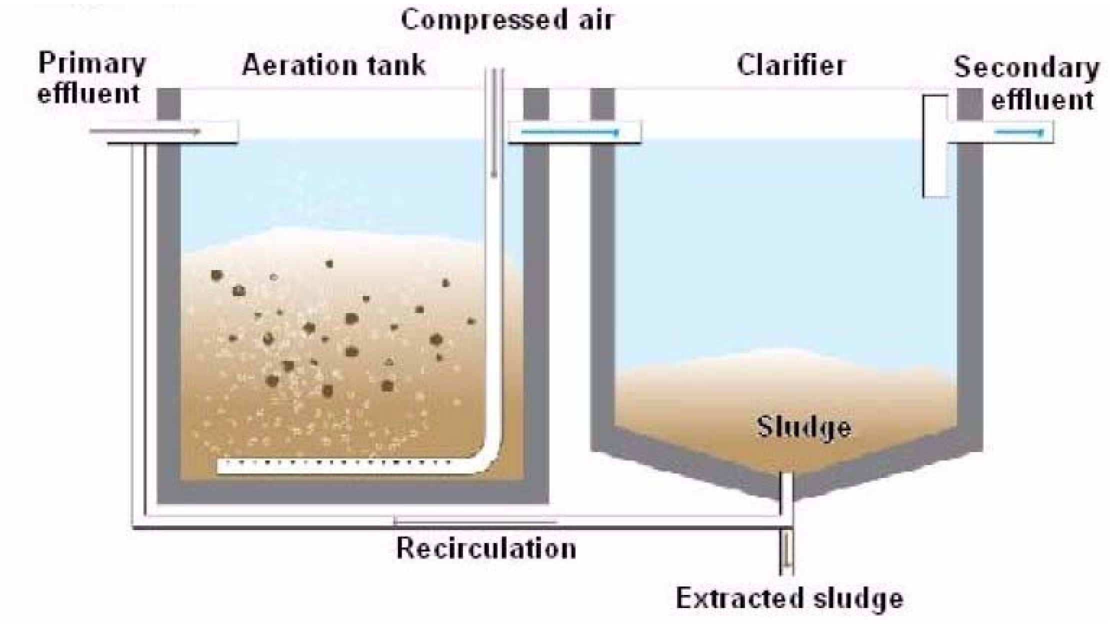

Figure 2–13: Activated sludge system example two

2.27 To achieve specific effluent goals for BOD, nitrogen and phosphorus, different adaptations and modifications have been made to the basic Activated Sludge design. Aerobic conditions, nutrient-specific organisms (especially for phosphorus), recycle design and carbon dosing, among others, have successfully allowed Activated Sludge processes to achieve high treatment efficiencies.

Rotating biological contactor system

2.28 Rotating biological contactor systems (refer figures 2–13, 2–14 and 2–15) normally make use of bar screens and/or comminutors, grit chambers, primary settling tanks, secondary tanks, and digesters, which are operated in the same manner as those of trickling filter systems. The rotating biological contactor (RBC) is a simple, effective method of providing secondary wastewater treatment. The system consists of biomass media, usually plastic, that is partially immersed in the wastewater. As it slowly rotates, it lifts a film of wastewater into the air. The wastewater trickles down across the media and absorbs oxygen from the air. A living biomass of bacteria, protozoa, and other simple organisms attaches and grows on the biomass media. The organisms then remove both dissolved oxygen and organic material from the trickling film of wastewater. Any excess biomass is sloughed-off as the media is rotated through the wastewater. This prevents clogging of the media surface and maintains a constant microorganism population. The sloughed-off material is removed from the clear water by conventional clarification. The RBC rotates at a speed of one to two rpm and provides a high degree of organic removal.

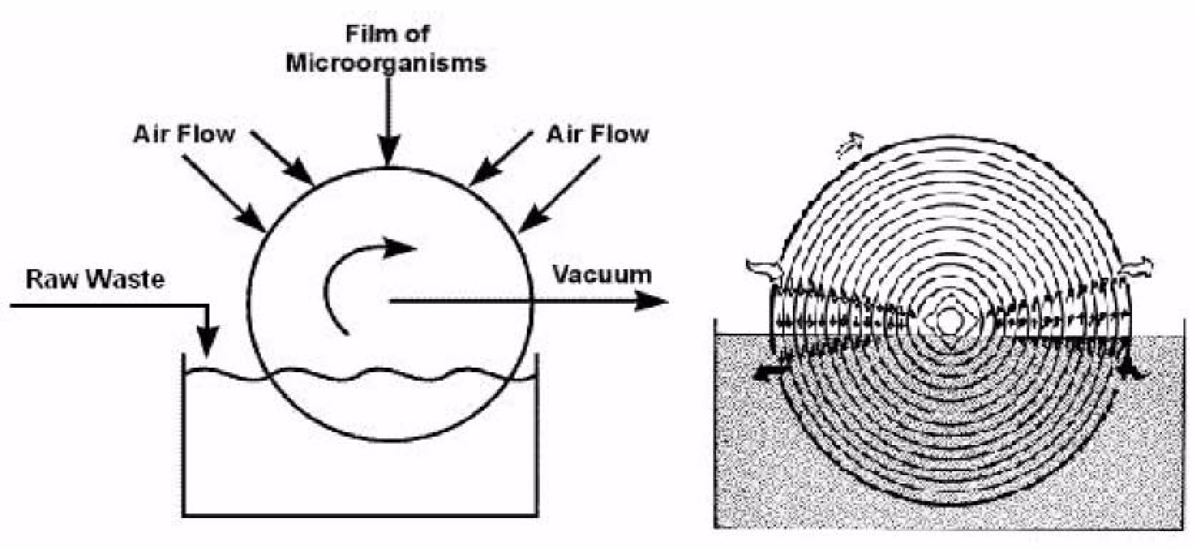

Figure 2–14: Rotating biological contactor

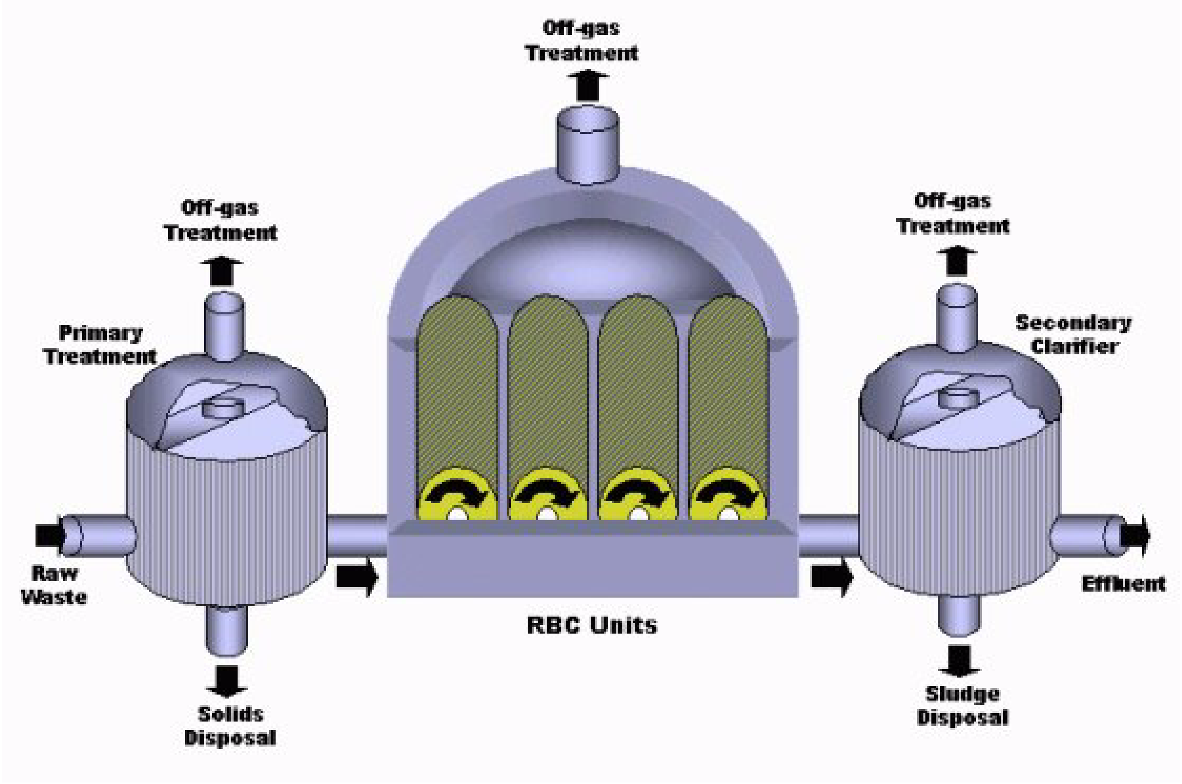

Figure 2–15: Rotating biological contactors preceded by pre-treatment and followed by secondary sedimentation

Figure 2–16: Rotating biological contactor

Imhoff tank system

2.29 Imhoff tank systems normally make use of bar screens and/or comminutors, grit chambers, primary settling tanks, secondary settling tanks, and digesters, which are operated in the same manner as those of trickling filter systems. An Imhoff tank is a combined sedimentation or settling tank and digestion tank (*see* figure 2–17). It consists of an upper compartment for settling out solids from slowly flowing sewage and a lower compartment for anaerobic digestion of the sludge. The upper compartment forms a channel with an approximately 20 cm slot in the bottom. Sides of the slot have a 1 horizontal to 1 1/2 vertical slope and are overlapped to prevent gases formed by digesting sludge from escaping into the upper or 'flowing-through' compartment.

2.30 With an average flow, solids settle in the upper compartment in two to two and a half hours, pass downward through the slot, and settle to the bottom of the lower compartment where they are digested. Accumulated solids are removed periodically through a sludge draw-off pipe having its inlet about 30 cm above the tank bottom. Design of the upper or 'flowing-through' compartment is based on the retention period. The lower or digestion compartment is designed to hold 85 litres per capita below a plane 45 cm beneath the bottom of the slot. If sludge from secondary settling is returned to this compartment for digestion, the capacity of the compartment must be increased to 130 L per capita.

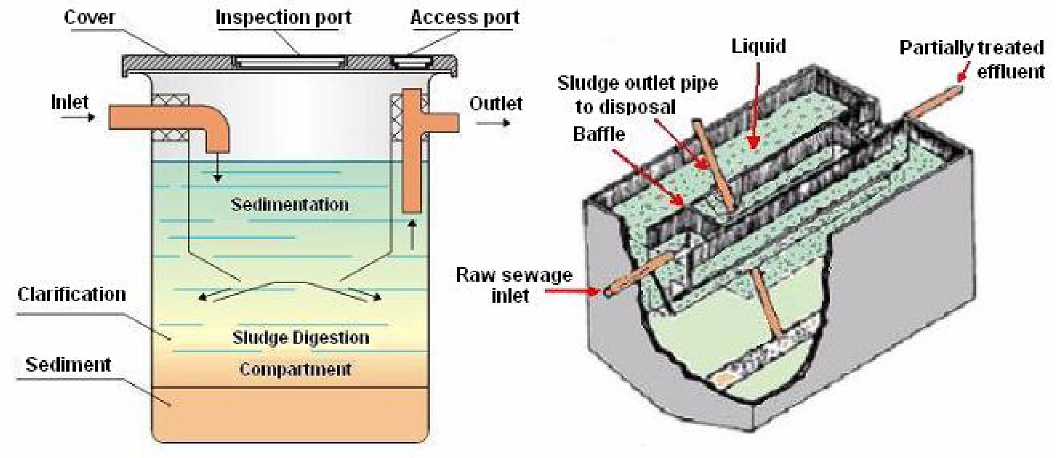

Figure 2–17: Imhoff tank schematic

Sewage oxidation ponds

2.31 Sewage oxidation ponds (lagoons) offer economical secondary sewage treatment with relatively low initial cost. These ponds are 0.8–1.2 m in depth, and may be used singly, in parallel, or in a series following primary treatment (*see* figures 2–18 and 2–19). Their use is particularly suited to locations with available land and warm climates. Their ability to absorb shock loads and ease of operation and maintenance make them desirable treatment units. Biological life in ponds use the organic and mineral matter in the sewage for food to produce more stable products. The products often stimulate abundant growth of algae and other vegetation. Solution of oxygen from the atmosphere, and the ability of vegetation to produce oxygen when exposed to sunlight, help maintain aerobic conditions. The lagoons will develop an odour similar to freshwater ponds in wooded areas. Allowable loading can vary from 125–2000 persons per hectare depending upon the location. Where complete treatment is to be provided by ponding, the cells are known as raw sewage lagoons, with depths of 1–1.5 m and reduced loading.

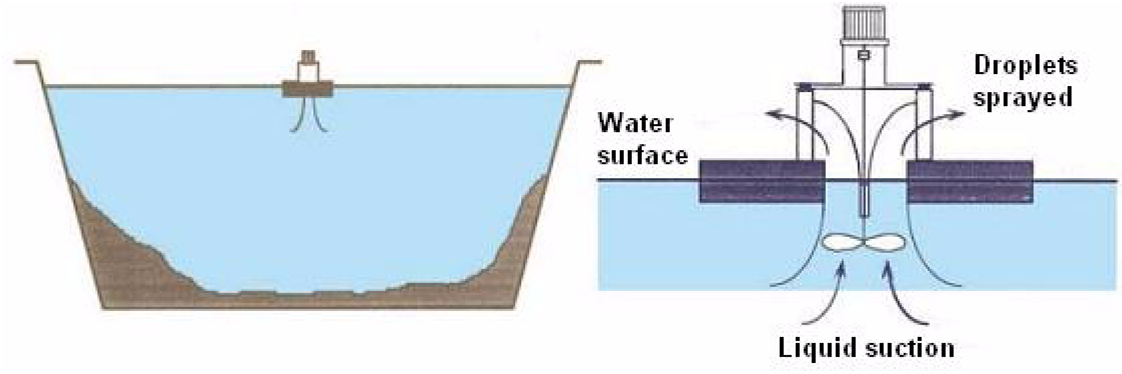

Figure 2–18: Sewage oxidation ponds schematic

Figure 2–19: Sewage oxidation ponds

Septic tank and tile drains

2.32 **Septic Tanks.** Septic tanks (*see* figure 2–20) may be used to serve small installations where the effluent can be disposed of through leaching wells, subsurface tile systems, or artificial subsurface filter systems. When sewage enters a septic tank an equal volume of liquid is discharged from the tank. The primary purpose of the septic tank is to condition the sewage so that the discharged liquid will not clog the disposal system.

2.33 A septic tank combines two processes. Sedimentation takes place in the upper portion of the tank, and the accumulated solids are digested by anaerobic decomposition in the lower portion. As sewage from a building enters a septic tank, its rate of flow is reduced so that the heavier solids sink to the bottom and the lighter solids including fats and grease rise to the surface. These solids are retained in the tank, and the clarified effluent is discharged. With good care and efficient operation, removal of solids maybe as high as 60 per cent, but at times the solid content of the effluent may equal or exceed that of the influent. Clogging of the disposal system will vary directly with the amount of suspended solids contained in the septic tank effluent.

2.34 Septic tanks do not accomplish a high degree of bacterial removal. Although the sewage undergoes treatment in passing through the tank, this does not mean that the infectious agents will be removed; hence, septic tank effluent cannot be considered safe. The liquid that is discharged from the tank is, in some respects, more objectionable than that which goes in; it is anaerobic and malodorous. However, this does not detract from the value of the tank. Further treatment of the effluent, including the removal of pathogens, is effected by percolation through the soil. In order not to disturb the bacterial action of the septic tank, disinfectants and bleach must never be flushed down toilets connected to septic tanks.

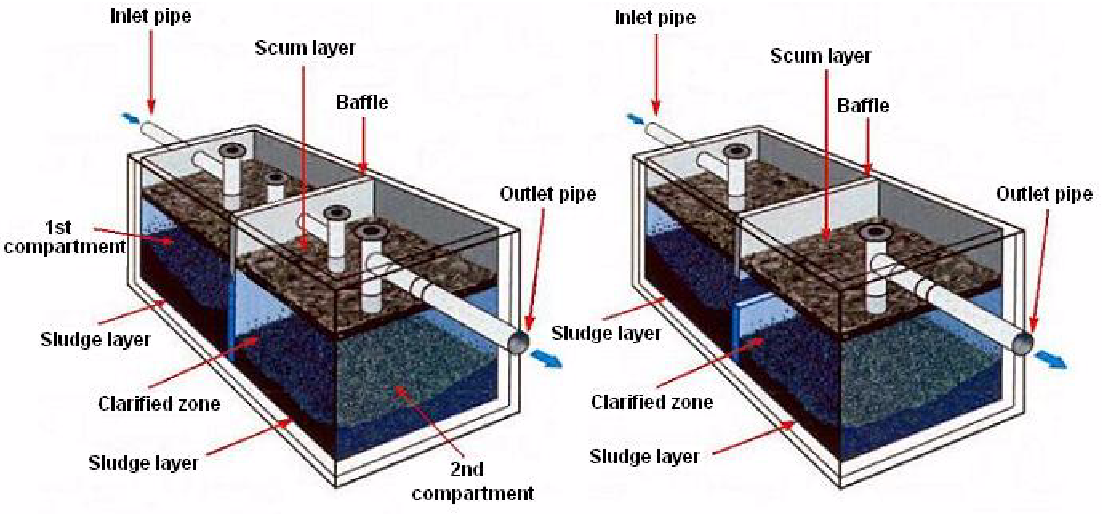

Figure 2–20: Typical septic tanks-dual chamber tank (left) and single chamber tank (right)

2.35 Septic tank capacity should equal a full days flow plus an allowance of from 15–25 per cent for sludge capacity. The minimum desirable size of the tank is 2000 litres. The tank's length should not be less than two or three times the width; liquid depth should not be less than 1.2 m for small tanks and 1.8 m for large tanks. Manholes should be provided over the inlet and outlet pipes for observation and maintenance. Baffles should be located approximately 45 cm from the ends of the tank, and should extend approximately 45 cm below and 30 cm above the flow line. Ells or tees may be used in place of wooden baffles. If these are used they should also extend at least 45 cm below the flow line. The elevations of the inlet and outlet pipes should provide free flow through the tank. This can be done by setting the bottom of the inlet pipe 8 cm above the water level. Some sludge from another operating septic tank or several shovels of fresh animal manure should be added to the new septic tank to facilitate its initial operation. A septic tank servicing an average size home of five people will need to be desludged every three to five years.

2.36 **Tile fields.** Tile fields are also known as 'soak-aways', drain fields, drainage fields, leach fields and absorption fields. Tile fields (*see* figure 2–21 and 2–22) with lines of cement or clay tile laid at least 45 cm underground with open joints are used to dispose of settled sewage into the ground. Fibre pipe with holes bored in the lower portion to allow drainage may also be used for these drain lines. A distribution box is essential for every absorption-field system to ensure equal distribution of the effluent to the several lateral lines, and to prevent overloading and failure of one line while the others are left empty. At least two lateral lines should lead from the box, and enough additional laterals should be connected to the box to provide the required effective percolation area.

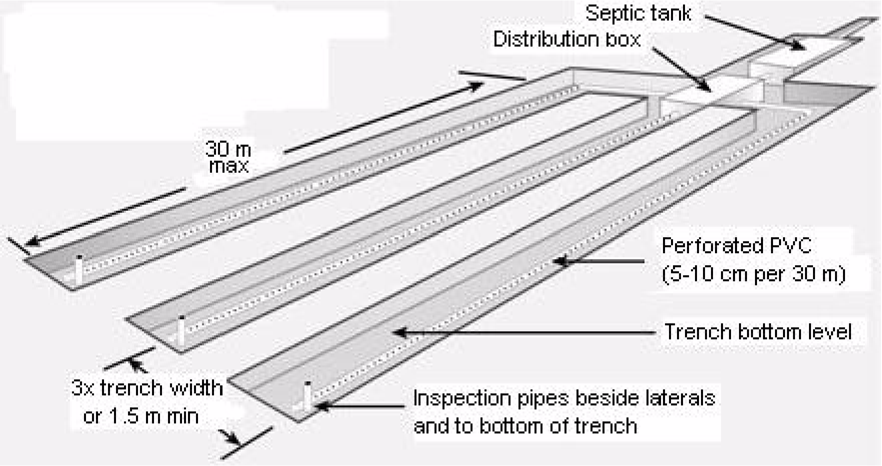

Figure 2–21: Tile field typical layout

2.37 The design of the system can be varied to meet most topographic conditions encountered, and to give proper grade and alignment for all laterals. Normally, the individual laterals should not be over 18 m long, with a maximum length of 30 m. The trench bottom and tile distribution lines should be laid at a grade of 5–10 cm per 30 m and never exceed 15 cm per 30 m. Use of more and shorter laterals is preferred because, if something should happen to disturb one line, most of the field will still be serviceable. Many different designs may be used in laying out subsurface disposal fields. The choice will depend on the size and shape of the available disposal area, the capacity required, and the topography of the disposal area.

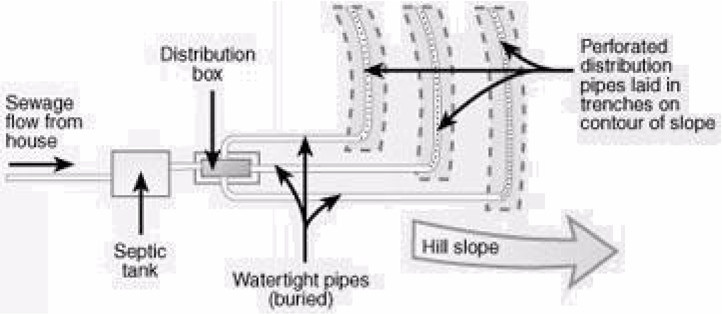

Figure 2–22: Tile field layout for a sloping site

2.38 Not all soils are porous enough to permit use of a tile field disposal system. First test the percolation rate of the soil in the proposed tile field area to determine the speed with which the settled sewage will pass into the soil. Also determine the total tile field area required to serve the installation adequately.

2.39 The required tile field area is determined by the soil percolation test. This test should be performed by qualified sanitary engineering personnel.

2.40 Once a tile field is constructed, all traffic must be excluded by fencing or posting to prevent crushing the tile. Planting shrubs or trees over the field is not a good practice, because the roots will clog the tile lines; however, grass over the lines assists in removing the moisture and keeping the soil open. Freezing rarely occurs in a carefully constructed system kept in continuous operation.

2.41 Leaching wells, sometimes called dry well or seepage pits, can be used with a septic tank. Leaching wells usually are dry-laid masonry or brick-lined wells without any masonry at the bottom; the sewage flows from the septic tank into them and leaches out into the soil. Floating solids collect in the top and settling solids in the bottom of the well. The well’s leaching capacity is exhausted when the solids accumulate and clog the surrounding soil. The leaching well works on the same principle as the tile field, but leaching is a less desirable method for sewage disposal. Leaching wells are suitable where the ground-water table is below elevation. When located in fine sand, surrounding the walls with graded gravel increases the leaching area.

Aerated water treatment systems.

2.42 Aerated water treatment systems (AWTS) have superseded septic tanks in many parts of rural Australia, because they are much more efficient in reducing the organic load of domestic effluent.

2.43 The conventional AWTS treats blackwater (water containing human excrement from a toilet) and/or greywater (wastewater from a hand basin, bath, shower, kitchen, laundry) using aeration to produce treated effluent.

2.44 The conventional AWTS incorporates two plastic or concrete tanks, each with a capacity of about 2500 L (*see* figures 2–23 and 2–24). The process involves primary sedimentation, anaerobic and aerobic treatment, secondary sedimentation and clarification, and disinfection using chlorine or ultraviolet irradiation. The treated effluent is discharged into the environment via surface irrigation, absorption trench or mound.

2.45 The maximum AWTS design capacity is for effluent produced by 10 persons on domestic premises. Maximum loads are: a daily flow of 150 L per person, an average daily BOD of 70 g oxygen per person, an average daily suspended solids rate of 70 g per person, an average daily total nitrogen of 15 g per person, and an average daily total phosphorus of 2.5 g per person. Some AWTS use two aerobic biological treatment tanks and their maximum design capacity is significantly greater.

2.46 AWTS tanks should be desludged every three to five years.

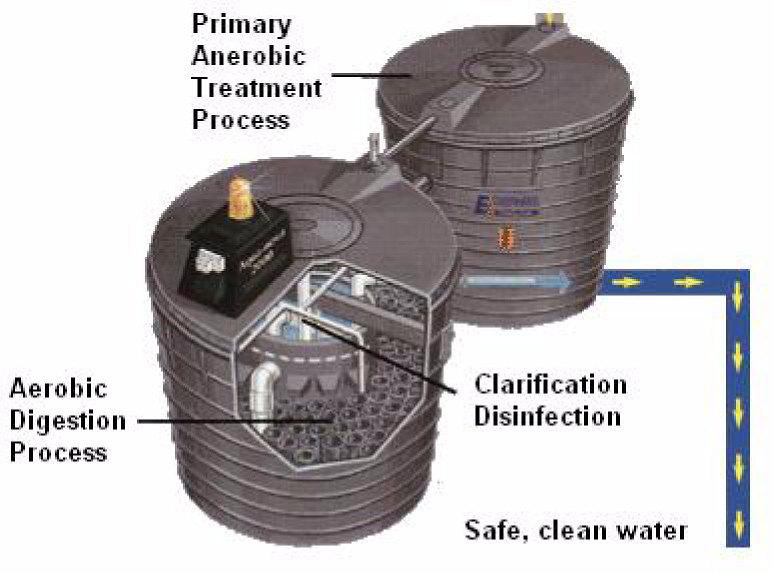

Figure 2–23: Dual tank aerated water treatment system

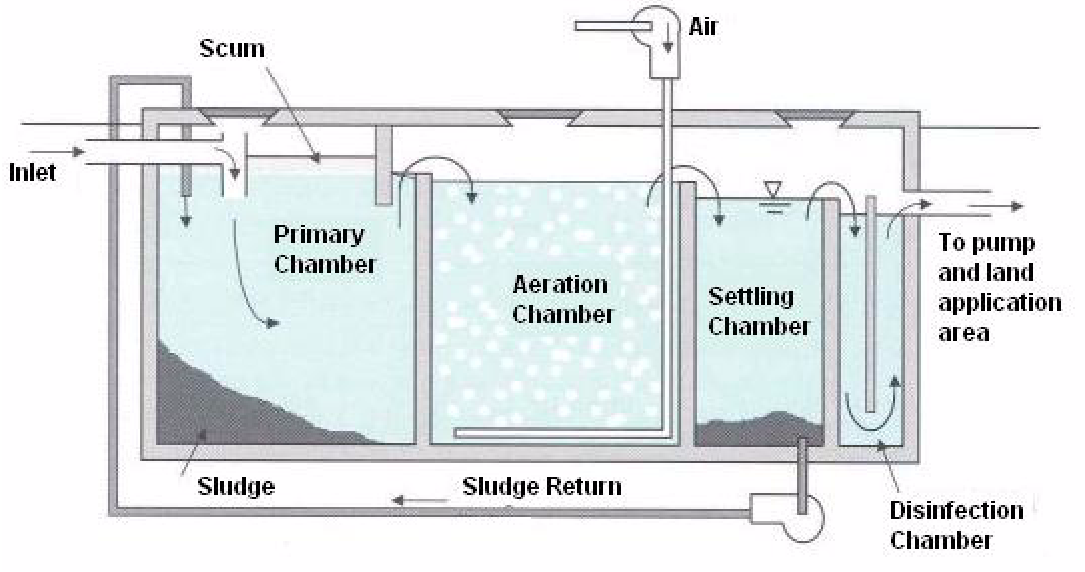

Figure 2–24: Fully encapsulated aerated water treatment system

Tertiary treatment

2.47 Increasingly, the effluent from secondary treatment systems is unacceptable because of increased recreational, domestic, and industrial requirements on the receiving body of water and more stringent stream standards. In such cases tertiary treatment can be employed to further reduce the solids and organic content of the effluent. This treatment can employ conventional processes with an increased detention time to allow for greater removals, or the operations installed for tertiary treatment can involve more exotic and expensive equipment such as electrodialysis units or ion exchange columns. In tertiary treatment, emphasis is placed on absorptive processes, such as the use of activated carbon; more efficient oxidation, as with ozone; foam separation of impurities; and demineralisation using reverse osmosis or distillation.

BIOCHEMICAL OXYGEN DEMAND CONCEPT

2.48 Sewage when ‘fresh’ has a musty odour, a grey colour, and contains both organic material and sufficient dissolved oxygen to support the growth of aerobic bacteria. Aerobic bacteria, as do humans, need a food supply and a source of free oxygen to survive. The food supply is furnished by the organic material in sewage, and the free oxygen is available as dissolved oxygen (DO). The DO is depleted as the aerobic bacteria attack the organic material contained in the sewage. Some of the DO can also be depleted through chemical action. The sewage will become ‘stale’ and then ‘septic’ as DO is depleted. Septic sewage contains no DO, and all bacterial action will be anaerobic.

2.49 The amount of oxygen necessary for the stabilisation (decomposition) of organic material in sewage under aerobic conditions is called BOD. It is an important indication of the amount of organic matter present in the sewage. The BOD test is a measure of the oxygen requirements of bacteria and other organisms as they feed upon and cause decomposition of organic matter. A high BOD will result in water becoming anaerobic (depleted of oxygen). BOD is therefore a measure of the organic load placed on the treatment facility. Industrial non-organic wastes can also deplete oxygen in the water, and this is measured by the chemical oxygen demand (COD) test.

2.50 COD is a measure of the oxidisability of waste, expressed as the equivalent amount in oxygen of a strong oxidizing agent consumed by the waste under fixed laboratory conditions. The dichromate reflux method is preferred over other methods using other oxidants such as potassium permanganate because of:

a. its superior oxidising ability,

b. applicability to a wide range of wastes, and

c. ease of use.

2.51 In the dichromate reflux method, a predetermined amount of waste is dissolved or dispersed in water and oxidised by potassium dichromate in a strong sulphuric acid medium with silver sulphate as the catalyst under reflux for two hours. The residual dichromate is determined by titration with standardised ferrous ammonium sulphate. In the case of wastes containing chlorine, mercuric sulphate is added to reduce chloride interference. The result of analysis for COD is expressed in mg/L (ppm).

2.52 BOD is normally expressed in mg/L or parts per million for a specified time and temperature, the standard being five days at 20ºC. The five-day, 20ºC BOD does not represent the total demand of a sample for oxygen. Only about two-thirds of the total oxygen demand of a domestic sewage sample is satisfied in five days at 20ºC, and almost all of the demand in 20 days at 20ºC. It would be very time-consuming to attempt to determine the total demand by incubating samples for 20 or more days. For this reason the five-day BOD test has been accepted as a practical standard.

2.53 The five-day BOD test is used as a control at nearly all sewage treatment facilities. The adequacy and degree of sewage treatment may be judged by the total reduction that occurs in the five-day BOD of the sewage as it flows through the sewage treatment facility. Also, standards are established by various governmental control agencies which set limits on the five-day BOD of treated sewage that may be legally discharged into a receiving stream.

2.54 Normally treated sewage effluent should have a suspended solids not exceeding 30 mg/L and a BOD not exceeding 20 mg/L. This standard is often referred to as the 30:20 standard. Sewage effluent discharged into a river should have a BOD not exceeding 4 mg/L. This can be achieved by diluting the effluent with clean water prior to discharge. Most rivers can easily assimilate affluent with a BOD of 4 mg/L without affecting fish and other aquatic life, so that effluent complying with the 30:20 standard is generally safe.

2.55 The general procedure for determining a BOD involves filling two BOD bottles with the water sample that has had its pH corrected to 7, and any chlorine present neutralized with three drops of a one per cent solution of sodium thiosulphate. DO is measured in the first bottle at time zero, and in the second bottle after five days storage in the dark at 20ºC. The difference between the two when multiplied by the dilution factor gives the BOD in mg/L or ppm. This is the oxygen consumed by microorganisms in the sample as they digest the organic matter present, over five days at 20ºC.

2.56 A rapid BOD can be determined in two and a half days at 37ºC and this has been determined to be equivalent to the five day test at 20ºC.

SEWAGE SAMPLING AND ANALYSIS

2.57 **General.** The purpose of sewage sampling and analysis is to ensure adequacy of sewage treatment or to identify problem areas in its operation. Normally, health personnel will not be equipped to analyse sewage samples, but they should know the purpose and procedures of conventional sewage analysis procedures.

2.58 **Sampling.** Sampling is conducted on the influent to a treatment system and the effluent after treatment. Sampling is also conducted at intermediate points or between components of the entire treatment system. There are two types of sampling techniques.

a. **Grab Sampling.** This is a sample of sewage taken at a designated time. It involves nothing more than collecting a designated amount of sewage in a container at a specific point in the system.

b. **Composite Sampling.** In as much as the quantity and quality of sewage vary significantly during a 24-hour period, a grab sample is not a good representation of the characteristics of sewage. The composite is taken by mixing together samples that have been collected at regular intervals (usually one-hour) over a 24-hour period. Because the quality and quantity of sewage vary throughout this period, the samples should be proportional in size approximately to the rate of flow at the time they are taken. The actual collection technique for either grab or composite samples is to use a dipper or can at least five cm in diameter to collect the sewage at mid depth in the sewer or conduit. Composite samples can also be collected automatically. A number of types of automatic samplers are available. Avoid excessive aeration of the composite sample and refrigerate the sample until it can be analysed. Analysis should be conducted as soon as possible, because sewage characteristics will vary with time.

2.59 **Sewage analysis**:

a. **Settleable and Suspended Solids (SS).** This measurement checks the efficiency of solids removal in treatment units. A similar term is non-filterable residues (NFR). Both SS and NFR are measured in mg/L.

b. **Biochemical Oxygen Demand.** This measurement indicates the amount of organic matter in sewage.

c. Other tests commonly used to evaluate the adequacy of treatment include pH, FAC, COD, and DO.

d. Refer to part 3 for additional information on sampling procedures.

POLLUTION

2.60 Pollution is one of the greatest abuses of our natural water resources. All foreign material added to a natural body of water is considered pollution. Overloading a natural body of water beyond its reserve or recuperative capacities with raw sewage, improperly treated sewage, or industrial wastes is a very serious matter. If the volume and velocity of the stream are not sufficient to handle the quantity of effluent being discharged great environmental damage can occur.

2.61 Everybody of water has a limited capacity for receiving sewage and other organic wastes by means of dilution. The full use of this capacity results in a loss of any reserve capacity and produces nuisances or reduces the quality of the stream. These detriments are classified as physical, chemical, and bacterial.

2.62 The physical detriments include the offensive odours of organic matter putrefaction; unsightliness of floating solids, oils, grease, scum, and debris; and turbidity and colour caused by dissolved and suspended matter. The body of water's ability to neutralise these effects is determined by its volume and velocity. For example, if a stream is flowing swiftly, bulky deposits will not appear, and the larger solids are broken up and carried downstream. However, debris and larger floating solids may still be a problem. Further dilution of these offending wastes as they are carried downstream likewise reduces odour and discolouration. Usually, these physical nuisances are not as important as the other types, and they are prevented by primary sewage treatment. However, a stream may be heavily overloaded by the effluent from a modern sewage treatment plant simply because the stream does not have the biological ability to handle the amount of organic matter being discharged from the plant.

2.63 Chemical detriments to a body of water include the depletion of oxygen in the water by the biochemical oxidation of organic matter. When total exhaustion of the dissolved oxygen occurs, odours and destruction of plant and fish life result. Secondly, other chemicals primarily from industrial wastes may be toxic, attack concrete structures, discolour the waters, destroy paints on boats, and more important, render the water unsuitable as a source of water supply by making it difficult or uneconomical to treat. For example, the discharge of phenols into a stream used as a water supply will not be removed with normal treatment methods, and with chlorination the water is rendered unpalatable by the formation of chlorophenols.

2.64 The last type of detriment is the microbial pollution caused by sewage effluent. A test for the most probable number of heat tolerant coliform organisms is of significance, particularly when the body of water is used as a source of water supply or as a bathing area, or if it passes over shellfish areas. A body of water's capacity to cope with this type of pollution is a function of dilution and distance from the point of discharge to the area of use. It has been found that most pathogenic bacteria die-off when released from the gastrointestinal tract into the marine or aquatic environments. The numbers of surviving bacteria tend to form a geometrical progression in time; that is, during an interval of time, the bacteria are reduced by a constant proportion of the number existing at the beginning of that interval. This phenomenon is called the geometric death rate.

2.65 With each of the three types of pollution mentioned, physical, chemical, and microbial , dilution in the stream volume is one indication of the receiving capacity of the stream. Microbial and organic chemical pollutants, however, are subject to other means of purification, and are the basis for what is known as self-purification of streams.

2.66 A polluted stream undergoing self-purification can be divided into four zones: zone of degradation, zone of active decomposition, zone of recovery, and zone of cleaner water.

2.67 Within the zone of degradation is where the pollutant has recently been introduced. The DO can be reduced to less than one-half of its original value; algae and fish life are declining; water is turbid; sludge deposits are forming on the stream bed; and typical bottom worms, together with sewage fungi, appear.

2.68 In the zone of active decomposition, the DO can be reduced to zero; fish life is absent; water is darker and greyish in colour; odours from putrefaction of organic matter including hydrogen sulphide and methane gases are given off; a scum may appear on the surface; and threadlike organisms of greyish, pink, and cream tints appear.

2.69 Through the zone of recovery the DO increases, the water is less turbid with reduced unpleasant odours given off, algae reappear, fungi disappear, and some of the hardier fish such as carp appear. Entering the zone of cleaner water, the DO approaches saturation, the natural stream conditions are restored, and trout and other game fish appear.

2.70 Although the physical appearance of the stream and the animal and plant life observed are important factors in judging stream pollution, it should be remembered that the indices (primarily pH, DO, BOD, SS, and nutrients) are the most significant measures of stream pollution.

a. The five day BOD for a very clean river is one or less; for a clean river 2 to <3; for a fairly clean river 3 to <5. For a river of doubtful condition 5 to <10, and for river in bad condition 10 or more.

b. The concentrations of oxygen in water at saturation, (at normal atmospheric pressure) at different temperatures, are: 14.66 mg/L (0ºC), 12.37 mg/L (5ºC), 10.92 mg/L (10ºC), 9.76 mg/L (15ºC), 8.84 mg/L (20ºC) and 8.11 mg/L (25ºC).