MICROBIOLOGY (COURSE MATERIAL

Semester – IV (CC 9)

Unit IV: Waste Management

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SYLLABUS: UNIT 4: WASTE MANAGEMENT

Liquid waste management: Composition and strength of sewage (BOD and COD), Primary, secondary (oxidation ponds, trickling filter, activated sludge process and septic tank) and tertiary sewage treatment

- ## Liquid wastes from residential areas

In urban areas, the liquid wastes from residential areas are often referred to as domestic wastewaters. These wastewaters come from our day-to-day living and include those from food preparation, washing, bathing and toilet usage.
Black-water and grey-water are produced from domestic dwellings with access to a piped water supply and also from business premises and the various institutions, such as schools and health centres, found in residential areas. The term *sewage* is used to describe a combination of all these types of liquid waste, frequently also with surface run-off.

In many towns and cities in the world, sewage is collected in underground **sewers** that carry the effluents to a sewage treatment workstation (**Effluent** is another term for wastewater that flows out from a source.) At the treatment workstation, the sewage is cleaned by various physical and biological processes before being discharged into a river or lake. It may be possible to reuse the treated water, typically for irrigation.

The quantity and type of liquid waste generated in a residential area depends on several factors, such as population size, standard of living, rate of water consumption, habits of the people and the climate. It also depends on the number and type of institutions such as schools and health centres in the area.

❖ Liquid wastes from commercial areas

The wastewaters from commercial areas comprising business establishments, shops, open market places, restaurants and cafes – will mostly resemble those from households. This is because only human-related activities are undertaken in such areas, as opposed to other activities such as industrial production. Effluent from restaurants and cafes may contain high levels of oil from cooking processes but this can be overcome by using a **grease trap** in their outlet pipes. A grease trap consists of a small tank or chamber which slows the speed of effluent flow. In the grease trap, fats, oils and grease float to the top of the wastewater and form a layer of scum that is contained within the tank. This can then be removed and disposed of as solid waste. Relatively clean water exits from the grease trap for disposal.

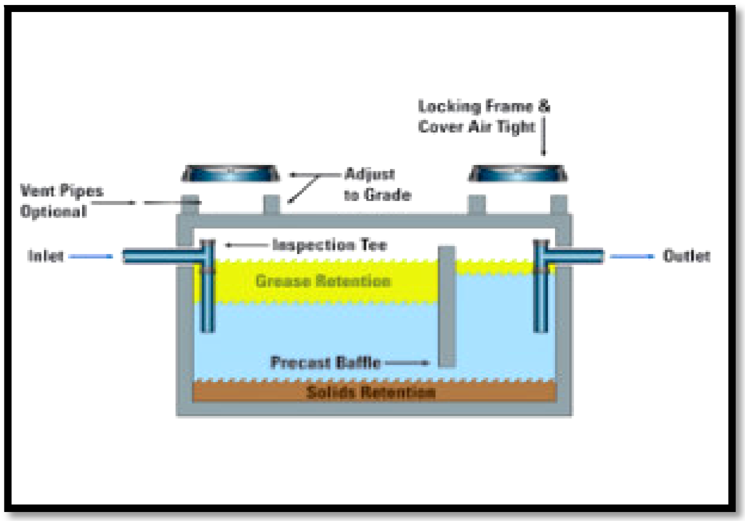

Figure: Grease Trap

The quantity of wastewater generated per person in a commercial area will be less than it would be at home because the only time spent there is during the working day, and so activities such as bathing are not usually undertaken at these establishments.

❖ Liquid wastes from industrial areas

In industrial areas liquid wastes are generated by processing or manufacturing industries and service industries, such as car repair shops. The type of industry determines the composition of the waste. The wastewaters from facilities that make food products will not be harmful to humans, but those from other industries may contain a variety of chemical compounds, some of which may be hazardous and therefore potentially harmful. Industrial wastewaters which contain hazardous substances must be treated, and the substances removed before the wastewater is discharged to the environment. The presence of hazardous materials is one way in which industrial wastewaters are often different from domestic wastewaters. Another difference is that the flow rate can vary dramatically in some industries, for example, where production rates vary with the season, such as in the processing of certain food crops.

❖ Storm-water

Although not a form of liquid waste in the same way as wastes from residential, commercial and industrial areas, stormwater is also a form of wastewater. Stormwater can be contaminated with many different types of pollutant such as faecal matter, soil, rubber from vehicle tyre wear, litter, and oil from vehicles. Where there is sewerage network (a system of sewers), stormwater may be channelled into the sewers, or it may flow into open ditches.

❖ Characteristics of liquid wastes

Liquid wastes can be described according to their physical, chemical, and biological characteristics.

- **Physical characteristics of liquid wastes**

Solids

Wastewaters may contain particles of solid material carried along in the flow. These may be settleable solids or suspended solids. **Settleable solids** sink to the bottom (settle out) when the speed of flow is reduced, for example, when the wastewater is stored in a tank. **Suspended solids** are small particles that remain in suspension in the water; they do not dissolve in the wastewater but are carried along with it. The solids content can be measured by filtering out and weighing the solids in a given volume of water. The laboratory procedure is to weigh a filter paper, pour a measured volume of water through the paper, then dry it and weigh again. The difference in mass equals the mass of solids which can be expressed in terms of milligrams of solid matter per litre of water, in units of mg l^{-1}.

Temperature

Wastewaters are generally warmer than the ambient temperature. This is because warm or hot water may be included in the waste stream from domestic activities such as showering or from industrial processing. The temperature is given in degrees Celsius (°C).

Odour

Wastewaters can have an odour, usually due to generation of gases as a result of biodegradation in the wastewater. **Biodegradation** is the breaking down (decomposition) of organic substances by bacteria and other micro-organisms. **Organic** matter is any substance that is derived from living organisms, such as human and animal wastes, food waste, paper and agricultural wastes. Detecting odour tends to be a subjective process but it is possible to measure it in terms of odour units.

- **Chemical characteristics of liquid wastes**

Organic matter

Wastewaters from many different sources contain organic matter, which is a frequent cause of pollution in surface waters. If organic matter is released into a river or lake, bacteria and other micro-organisms that are naturally present in fresh water will degrade the waste and in the process they use dissolved oxygen from the water. If there is a lot of organic matter, then most or all of the dissolved oxygen may be used up, thus depriving other life forms in the water of this essential element. The oxygen taken up in degrading the organic matter is referred to as its **oxygen demand**. This can be determined by a measure called the **biochemical oxygen demand (BOD).** BOD tests are carried out in a laboratory and involve measuring the amount of oxygen used, usually over a period of five days, as the organic matter in the wastewater breaks down. The result is the amount of oxygen used in degrading the organic matter in the wastewater, which is expressed in milligrams per litre (mg l^{-1}).

There is also a chemical method of determining the quantity of organic matter called the **chemical oxygen demand (COD)** test. This test is much quicker than the BOD test, taking only about two hours to carry out. It depends on chemical oxidation of the organic matter rather than biological degradation. It involves boiling a sample of wastewater with a mixture of concentrated acids and a measured quantity of oxidising agent to oxidise the organic matter. The amount of oxidising agent remaining at the end of the test is measured. The amount that has been used up is equivalent to the amount of organic matter in the sample. The result is again expressed in mg l^{-1}. COD tends to give higher results than BOD because the chemical process can oxidise more material than the biological process.

Inorganic material

Wastewater also contains **inorganic** chemicals. This means any substance that has not come from animals or plants, so it includes a wide range of different chemicals as well as inert solids like sand and silt. Many inorganic chemicals are dissolved in the water and although some are harmless, others are pollutants that can damage aquatic life such as fish and other organisms that live in water. One example is ammonia (NH_3) which is present in human and animal excreta. Like organic matter, ammonia is broken down in the environment by natural processes. If ammonia is released into a river it is converted by the action of bacteria to nitrate (NO_3), which is less harmful. This natural conversion of ammonia to nitrate requires oxygen and is limited if there are excessive quantities of ammonia. Other examples of inorganic chemicals in wastewaters are chloride (from salt), phosphates (from chemical fertilisers and from human and animal wastes), and metal compounds (from mining operations or metal-plating plants).

- **Biological characteristics of liquid wastes**

Liquid wastes contain many different types of bacteria and other micro-organisms originating from human wastes and other sources. Many of these bacteria are beneficial and are responsible for the biodegradation of organic components of the wastes; others may be pathogenic. The presence of bacteria in wastewater is normal and expected, but it becomes a problem if the waste is not kept separate from people or if it contaminates clean water or food. The safe management and disposal of any waste containing human excreta is the most critical aspect of sanitation and hygiene and is essential to prevent the spread of infectious disease.

The composition of industrial wastewater will vary depending on the type of industry, the raw materials used, and the processes undertaken. Three of the most important producers of industrial wastewater in Ethiopia are the food industry, the textile industry and tanneries.

❖ The food industry

Food production is a priority in Ethiopia and plays a major part in the economy, with factories producing bread, beverages, sugar and several other products. Many of the production processes require large volumes of water and so most of the factories are located near rivers or boreholes.

Canneries

The volume of clean water required differs between canneries and the products being prepared, but ensuring cleanliness is obviously essential. For tomato paste, a popular food product in Ethiopia, it takes about 220 litres of water to produce 10 kilograms of tomato paste. Canning factories that produce tomato paste, such as the Merti Processing Factory in Oromia, generate both solid and liquid waste. The quantity of solid tomato waste may be as much as 15-30% of the total quantity of product (Faris et al., 2002). The wastewater from a cannery will contain organic solids, primarily from washing raw materials such as tomatoes, cleaning equipment, spillage and from floor-washing.

Meat packaging

Wastewaters are generated at animal yards, slaughterhouses and packing houses. The main sources are animal faeces, urine, blood and water that has been used for washing floors and surfaces. The pollutants in the wastewaters are organic and can decompose rapidly, generating unpleasant odours. If discharged to a water body, they will cause severe environmental pollution. The meat industry utilises thousands of litres of water per day depending on the size of the facility and the number of animals processed.

Dairies

Wastewaters from dairies may come from receiving stations (where milk is delivered from individual farms), bottling plants, creameries, ice cream plants, cheese production units and dried milk production plants. The wastewater from spillage, cleaning and washing usually contains milk which has a very high **polluting potential**. The polluting potential is the potential of the wastewaters to cause pollution, i.e. damage to the condition, health, safety, or welfare of animals, humans, plants or property.

❖ Textile industry

The raw materials for the textile industry are wool, cotton and synthetic fibres. The processing of wool and cotton involves removing natural impurities, such as dust, and imparting particular qualities relating to appearance, feel and durability. Water is used for washing at various stages, producing effluent that is likely to contain suspended solids and organic material from processing the fibres. It may also contain dyes and other chemicals, depending on the specific processes used in the factory. The outputs from these processes are used to make clothing and other textile products.

Tanneries

Ethiopia has the largest livestock population of all countries in Africa (TAM Consult, 2008) and tanning of animal hides is an important economic activity. There are 26 major tanneries in Ethiopia (UNIDO, 2012) producing a range of products from sheep, goats and cows including partly processed hides and finished leather.

Tannery effluent is highly polluting and is often discharged directly to nearby rivers without adequate treatment. It contains toxic (poisonous) chemicals such as chromium, sulphides and organic acids, as well as organic matter and solids. Chromium is a particular problem because it is an example of a heavy metal. **Heavy metals** are a group of toxic chemical pollutants that persist in the environment, i.e. they do not get broken down by natural processes. Tannery wastewaters are produced in large volumes and are considerably more polluting than wastewaters from most other industries. The treatment of tannery waste involves removing solids and organic matter from the effluent.

❖ Sewage

'Sewage' is a collective noun used to represent liquid or solid wastes carried in sewers. It consists of domestic water-borne wastes including human and animal excrete, washing waters and everything that goes down the drains of a town or a city. It also consists of industrial water-borne wastes as well as ground, surface and atmospheric waters which enter the sewerage system. The amount of sewage produced in our country is of the order of 3.61 million cubic metres/day (about 800 million gallons/day). About 30% of the above amount comes from urban areas. It is estimated that only about 20% of one day sewage production of our country is treated and utilized, and the rest (about 80%) still remains untreated and unutilized.

▪ Composition of Sewage:

The composition of sewage mainly depends upon per capita consumption of water and varies from place to place and season to season. The sewage composition can be studied under following two heads:

1. Chemical Composition:

Chemically, the sewage consists of approximately 99% water and 1% inorganic and organic matter in suspended and soluble forms. Lignocellulose, cellulose, proteins, fats, and various inorganic particulate matter exist in suspended state, whereas sugars, fatty acids, alcohols, amino acids, and inorganic ions constitute the soluble forms. However, on an average, the sewage of towns in our country contains about 350 ppm biodegradable organic matter, 52 ppm N_2, 45 ppm potassium and 16 ppm phosphorus. Salts of several heavy metals such as Zn, Cr, Ni, Pb, etc. are also present above permissible levels in sewage.

2. Microbial Composition:

The microbial population per millilitre of sewage may vary from a few lacs to several millions. Various types of microorganisms, viz., micro-fungi, bacteria and protozoa, collectively called 'sewage fungus', are known to grow profusely in sewage. In addition, viruses and many micro-algal genera have also been recorded from sewage. Bacteria occurring in sewage are mainly intestinal and soil inhabiting and their common types are *Coliforms, Streptococci, Clostridia, Micrococci, Proteus*, *Pseudomonas*, and *Lactobacilli.*

▪ Classification of Sewage:

Sewage may be classified mainly into two types, namely, domestic and industrial. All household wastes and human and animal excrete constitute domestic sewage, whereas the industrial wastes constitute industrial sewage.

Since industrial wastes vary greatly in their composition (some may be highly alkaline such as soda wastes, some highly acidic such as acid-mine drainage, and others toxic because of presence of heavy metals, antibiotics, pesticides, etc.), the treatment of industrial sewage proves highly difficult in comparison to domestic sewage.

- ## Characteristics of Sewage:

a) Biochemical Oxygen Demand (BOD) and Oxygen Consumption (OC) values are extremely high in sewage.

b) The sewage organic matter undergoes anaerobic or partial decomposition resulting in the production of obnoxious gases, namely, CH_3, CO and H_2S due to anoxic condition. Besides being toxic, these gases react with water and produce acids.

c) Production of acids in large quantity make the sewage more acidic thus making it unfit for supporting life activities.

d) Heavy metals are generally present in abnormal concentration in sewage.

e) All these characteristics of sewage, viz., anoxic condition, high acidity, high heavy metal concentration, and reduced photosynthetic rate due to poor illumination cause death of oxygen-dependent organisms such as aerobic microorganisms, plants and animals in sewage. This is the reason why sewage is dominated by organisms capable of growing in anaerobic environments.

- ## Disposal of Sewage:

Sewage disposal has become of prime importance now-a-days as it brings undesirable and harmful effects on living beings. Untreated or inadequately treated sewage is generally disposed of into natural water reservoirs without taking its pros and cons into account.

It is so either because we are indifferent to the consequences or because we assume that the water reservoirs are sufficiently large and so located that sewage-dilution prevents hazards.

However, we can no longer rely on disposed-sewage dilution in our natural water reservoirs; the solution of sewage pollution is not its dilution. It is necessary, therefore, that the sewage must be treated before its disposal so that we can, on one hand, save organisms including men from bad effects and, on the other hand, can utilized it to the maximum for our welfare.

Disposal of sewage as such or inadequately treated one, generally leads to following consequences:

a) Frequent dissemination of water-borne disease causing microorganisms in large number.

b) Depiction of dissolved oxygen in water leading to anoxic (oxygen-less) condition which may ultimately kill O_2 dependent aquatic life.

c) Creation of offensive odour and debris-accumulation due to which value of property decreases.

d) Increased danger of swimming in water and diminished value of water for other recreational purposes.

Treatment of Sewage:

Our objectives behind the sewage treatment would be to kill pathogenic microorganisms, prevent anoxia, raise the pH to alkaline side, increase photosynthetic rate, reduce organic content, etc. When these objectives are achieved by the way of treating the sewage, the conditions prevailing in a natural water reservoir are induced in sewage water and the latter can be reused.

Sewage treatment processes are many and varied. We will discuss only those sewage treatment processes which are generally applied in single dwelling unit situations and municipal situations.

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1. Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD; sometimes called Biological Oxygen Demand) represents the amount of dissolved oxygen needed by the microorganisms in a particular amount of water at 20°C in 5 days.

The strength of sewage is expressed in terms of BOD. The magnitude of BOD is related to the amount of organic material present in the sewage. A medium or strong sewage (having more oxidizable matter) has high BOD value, and a weak sewage (having less oxidizable matter) has low BOD value. Thus, BOD determinations provide the best information concerning the strength of sewage and the efficiency of sewage treatment processes.

Sewage BOD Determination

The BOD is determined by dilution of a measured amount of sewage with water that has been saturated with oxygen and incubation of the mixture at 20°C alongwith a control of dilution water alone. After 5 days, the residual oxygen in both control and test samples is measured by titration. The difference represents the oxygen consuming capacity of the sewage and is calculated to be expressed as parts per million (ppm) of oxygen taken up by the waste. The strength of the sewage in terms of pounds of BOD is calculated as follows :

$$\frac{\text{ppm 5 — day BOD} \times \text{gallons of sewage} \times 8.34}{1{,}000{,}000} = \text{pounds BOD}$$

BOD effect in Domestic Water

Whenever appreciable amount of strong sewage are emptied into natural waters such as streams, ponds, lakes, etc., the 7-8 ppm of free oxygen, which is normally present in water, is quickly utilized to meet out the oxygen demand of sewage. This results in a drop in oxygen level in water. When the oxygen drops below 3 ppm, the fish either leave or die. The anaerobic condition is attained and hydrolysis, putrefaction and fermentation by microorganisms follows with the result that the body of water becomes malodorous and cloudy and hence unsuited for recreational use, unfit for drinking, and other purposes.

2. Oxygen Consumption (OC)

OC represents the amounts of dissolved oxygen utilized by biotic communities for the oxidative decomposition of organic matter in one liter of water in one hour. Dissolved oxygen in sewage becomes totally depleted because of high oxygen demand and low photosynthetic rate. Photosynthesis in sewage comes down because of poor illumination as the suspended solids obstruct sun light. However, the depletion of dissolved oxygen leads to anoxic (oxygenless) condition.

Single Dwelling Unit Treatment Processes:

1. Outdoor Toilets:

Where plumbing installations cannot be undertaken for any reason, the toilets or water closets may be constructed outdoors. While this arrangement is undertaken, care could be taken to see that flies have no access to these and changes of drainage from these, joining water supplies, are eliminated.

2. Septic Tanks:

These are used for residential quarters (Fig. 32.1). All the residential sewage is passed through suitable pipes leading to a tank located at a suitable place and made of metal or concrete. The heavy particles of sewage settle down and undergo anaerobic decomposition whereas the gases and clear water are allowed to go out through perforated pipes ramified within the ground.

The septic tank device should be so fitted that the sewage does not drain by any chance into water supply of the residence. The sludge in the tanks must be periodically removed to prevent clogging of the pipes.

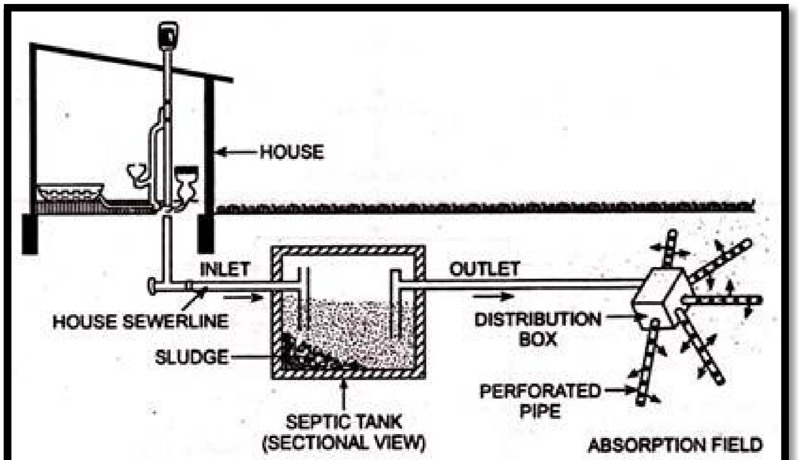

FIG. 32.1. Septic tank.

3. Imhoff Tank:

This is, in fact, a modification of septic tank and is generally used to treat larger community sewage (Fig. 32.2). It consists of two chambers, one above the other. The top chamber receives sewage and the heavier particles settle into the lower chamber and slowly decompose under anaerobic conditions.

The gas liberated (mainly methane) can be drawn out through a passage and utilized as fuel. The sewage effluent (remaining sewage water) is either let into larger body of water, or is subjected to aerobic decomposition. The sludge is periodically removed, aerated and used as manure.

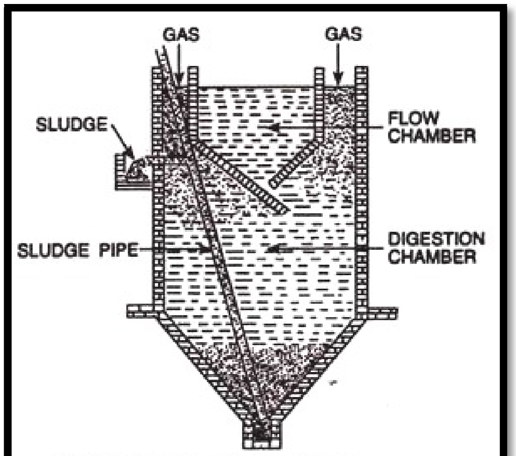

FIG. 32.2. Imhoff tank (sectional view).

Municipal Treatment Processes:

Municipal sewage treatment systems carry out various steps involved (Fig. 32.3). These steps are, namely, primary (or mechanical) treatment, secondary (or biological) treatment, and tertiary (or final) treatment.

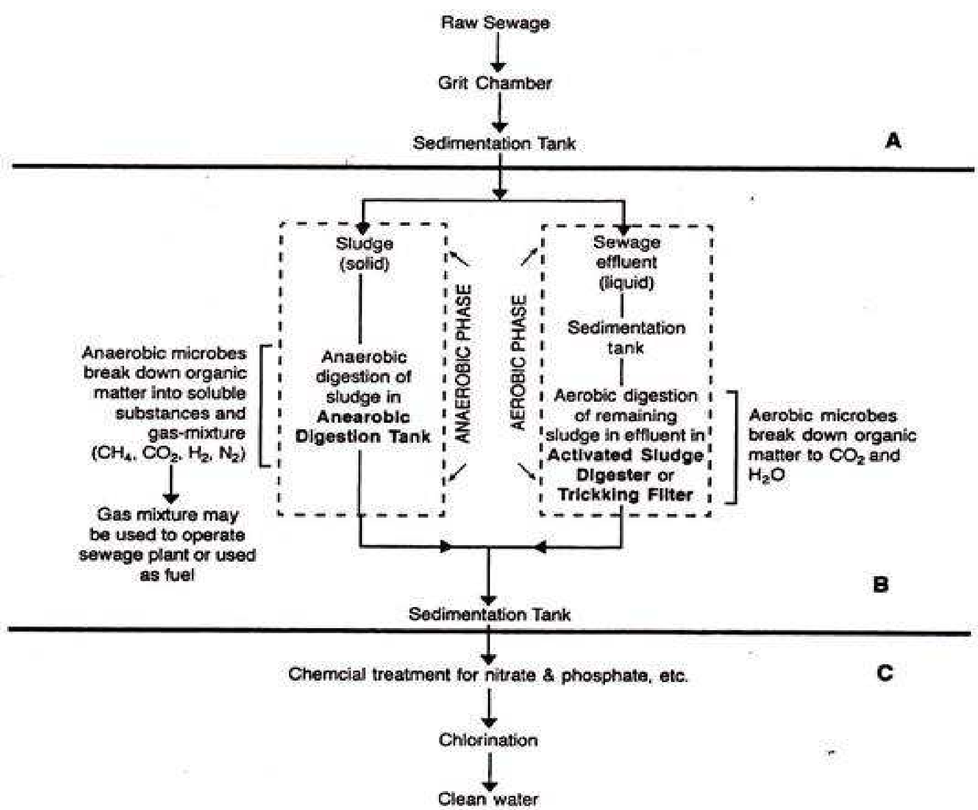

FIG. 32.3. Schematic representation of a modern municipal sewage treatment plant. A. Primary (mechanical treatment; B. Secondary (biological) treatment; and C. Tertiary (final) treatment.

1. Primary (or Mechanical) Treatment:

When the sewage arrives at a sewage treatment plant, it is first subjected to mechanical (or physical) means, viz., flowing, dilution and sedimentation to remove its coarse solid materials. The sewage is passed through a series of filters of graded openings and then allowed to flow through sedimentation units (tanks, basins, etc.).

Coarse solid materials are concentrated in and collected from sedimentation units; these particulate materials are collectively called 'sludge'. Following sedimentation, the sludge and liquid affluent are processed separately during secondary treatment.

2. Secondary (or Biological) Treatment:

This is purely a biological treatment of mechanically treated sewage and concerns microbial activity which biodegrades organic substrates and oxidizable inorganic compounds. This treatment accomplishes two important phases, namely, aerobic phase and anaerobic phase.

The aerobic phase consists of aerobic digestion of sludge by various filters (e.g., trickling filters), oxidation ponds and activated sludge process, and the anaerobic phase is represented by anaerobic digestion of sludge.

I. Aerobic Phase of Secondary Treatment:

(i) Aerobic Digestion in Trickling Filters:

Trickling filter consists of generally 6-10 feet deep bed of crushed stone, gravel, slag, or similar material. The sewage effluent is sprayed over the surface of the bed; the spraying saturates the effluent with oxygen. The bed surface becomes coated with aerobic microbial flora consisting of microalgae, micro-fungi, bacteria, and protozoa.

As the effluent seeps over, the aerobic microbes degrade the organic matter. However, the treated effluent collected at the bottom of the tank is passed to sedimentation tank and, like activated sludge process, the effluent follows tertiary treatment. Aerobic digestion of sewage organic matter in a trickling filter is a very slow process.

(ii) Oxidation Ponds:

Oxidation pond sewage-treatment is recommended for small communities in rural areas where suitable and sufficient land is available. Oxidation ponds (also called Lagoons or Stabilization Ponds) are generally 2-5 feet deep shallow ponds designated to allow direct wind action and algal growth on the sewage effluent.

Oxygen supplied from air and produced as a result of algal photosynthesis fulfils biochemical oxygen demand (BOD) of sewage effluent and thus helps in maintaining aerobic condition in sewage effluent. In such condition the aerobic microbes grow rapidly and digest organic matter. *Chlorella pyrenoidosa* is a common algal representative grown in oxidation ponds.

(iii) Activated Sludge Process:

In this process, the mechanically treated sewage effluent (serge liquid) is pumped into a sedimentation or settling tank wherein the sewage floes and settles out. A portion of sewage 'floe' is returned to activate a new batch of mechanically treated sewage effluent, and the rest is pumped to activate sludge digester where air is blown by several jets.

Thus, in the presence of plentiful oxygen, oxidation of sewage effluent is brought about by aerobic microorganisms which break down organic matter to CO_2 and H_2O. Now the effluent is passed through a sedimentation tank. Though about 90% of the organic matter of the effluent is digested via this process, the effluent still contains considerable amount of nitrate and phosphate, etc.
It is, therefore, not safe to discharge effluent at this stage into a large body of water ds both nitrate and phosphate can cause eutrophication. Now the effluent, which looks clear at this stage, is subjected to tertiary (final) treatment for further purification.

Activated Sludge

When we vigorously serate sewage, the finely suspended and colloidal material (including microbes) of it forms aggregates called 'floccules'. These floccules collectively result in the formation of sewage 'floc'. When this sewage floc is sedimented and then inoculated to a fresh vigorously aerating sewage, the floccule formation in the latter takes place in shorter time duration than the previous one. As a result of the repetition of this process, (*i.e.*, inoculation of sedimented floc to a fresh aerating sewage, sedimentation, inoculation of sedimented floc again to a fresh aerating sewage, etc.) a stage is reached where complete flocculation of a fresh sewage takes place in very short time duration, *e.g.*, a few hours. These particles of sedimented floc are called **'activated sludge'** and consist of large number of very actively metabolizing bacteria, yeasts, molds, and protozoa. The Ûse of activated sludge is of great significance in biological treatment of sewage as it reduces aeration period of sewage to 4-8 hours.

II. Anaerobic Phase of Secondary Treatment (Anaerobic Digestion of Sludge):

The sludge collected after primary (mechanical) treatment of sewage is subjected to anaerobic (oxygen- free) digestion in separate tank designed especially for the purpose. Since anaerobic condition prevails in this tank, the anaerobic microbes bring about digestion of organic matter by degrading them to soluble substances and gaseous products (methane, 60-70%; CO_2, 20-30%; and smaller amounts of H_2 and N_2).

This gas mixture can be used for operating power for the sewage plant or as a fuel. Recently, Municipal Corporation of Delhi has started supplying this gas mixture to about 100,000 people for cooking purposes.

Eutrophication

Eutrophication represents the excessive growth of photosynthetic microorganisms, especially the microalgae as a result of enrichment of natural waters with inorganic materials particularly nitrogen and phosphorus compounds. Sudden nutrient enrichment in sewage discharge or agricultural run-off triggers explosive algal blooms. But because of mutual shading, exhaustion of micronutrients and the presence of toxic products and/or antagonistic population, the algal population usually 'crashes'. The subsequent decomposition of the dead algal biomass by heterotrophic microbial population exhausts the dissolved oxygen supply in the water. This results in extensive fish-kills and septic conditions. Even if the process does not proceed to this extreme, the algal mats, turbidity, discoloration, and shifts in the fish population represent the undesirable changes in natural water sources as a result of eutrophication.

3. Tertiary (or Final) Treatment:

Since the sewage-effluent treated during secondary treatment process still contains non-biodegradable organic pollutants (if sewage contains industrial wastes) and mineral nutrients particularly nitrogen and phosphorus salts, it is subjected to tertiary (or final) treatment for their removal.

If not so, the sewage effluents containing nitrogen and phosphorus salts can cause serious eutrophication in aquatic ecosystems. Non-biodegradable organic pollutants are normally removed by using activated carbon filters whereas phosphorus and nitrogen salts by chemical treated.

Phosphorus salts are precipitated by liming and the nitrogen present mainly as ammonia is removed by volatilization (vigorous aeration at elevated temperature) at a high pH. These treatments result in a high-quality effluent which does not cause eutrophication.

The find step of tertiary treatment is disinfection which is commonly accomplished by chlorination using either sodium or calcium hypochlorite ($NaOCl$ or $CaOCl_2$ respectively) or chlorine. Now the effluent is clean water and is considered microbiologically safe even for human consumption.