In this method Hg^{2+} is first reduced to elemental Hg by $SnCl_2$ solution at room temperature. The elemental Hg is then swept by air into an absorption cell where nanogram (10^{-9} g) quantities of Hg are measured or estimated at an absorbance of 253.7 nm.

Follow the procedure with the 100 mL sample in a 500 mL distillation flask upto the removing of excess of H_2O_2 by boiling as given in dithizone method. After this, cool the solution and dilute it with distilled water to a volume of 250 mL (Fig. 21).

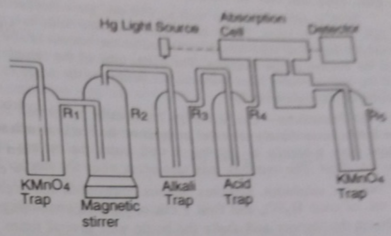

Fig. 21. Devapour generator system of mercury analyser.

Now add 2 mL of $SnCl_2$ (20%) in 10 mL of conc. HCl and 10 mL of 10% HNO_3 to the reaction vessel R_2. Mix the contents vigorously for about 3 – 5 minutes with a magnetic stirrer. Pump the resulting mercury vapour left in the reagents as impurity, through 3 mL of NaOH (20 – 22%) and 3 mL of H_2SO_4 (50%).

Now pass 1-2 mL of digested sample into R_2 containing 2 mL of Hg free $SnCl_2$ and 8-10 mL of 10% HNO_3. Again mix the contents vigorously for 3-5 minutes.

Pump the resulting Hg vapour through 20-22% NaOH in R_3, 50% H_2SO_4 in R_4 (to absorb moisture), and finally to the absorption cell, where absorbance is measured at 253.7 nm. Hollow cathode lamp is used as a light source.

In the end absorb Hg vapour (after the measurement) in 1% $KMnO_4$ + 10% H_2SO_4 in the outlet.

CHEMICAL SUBSTANCES INDICATIVE OF POLLUTION

1. Nitrogen – The nitrogen present in saline constituents is usually known as **ammonical nitrogen**, while nitrogen present in organic constituents as proteins, amines, amino acids is called **albuminoid nitrogen.** Both these can be estimated separately as ammonia using **Nessler's reagent.** The water sample is distilled after adding phosphate buffer (pH 7.4). The distillate contains ammonical nitrogen. The distillation is continued with the addition of alkaline $KMnO_4$ and this second distillate contains albuminoid nitrogen. Total organic nitrogen is estimated by Kjeldahl method. It can also be calculated by the difference between the value for total Kjeldahl nitrogen and that for free ammonia.

2. Nitrite nitrogen can be determined through the formation of a reddish purple dye produced by the coupling and diazotization of sulphanilic acid with 2- naphthylamine hydrochloride at pH 2.0 – 2.5.

DISSOLVED OXYGEN

The **dissolved oxygen (DO)** levels in natural as well as waste waters depend on physical, chemical and biological activities of the water body. The analysis of dissolved oxygen is very important in water pollution control as well as waste water control.

Winkler's method—(a) Collection of samples—When collecting a sample of cold water from a faucet or valve connection, open the faucet, or valve and insert a glass tube or one of pure gum rubber. This will not take all the water flowing from the opening; a major part should be wasted. Collect a sample for each determination in a 250 mL, narrow necked glass stoppered bottle. The glass or gum rubber tube is extended to the bottom of the bottle in order to avoid absorption of atmospheric O_2. Allow the bottle to overflow for about 10-15 minutes at the rate of 1-2 litres/minute and immediately stopper the bottle.

avoiding the formation of an air bubble below the stopper.

The hot sample is first cooled to the room temperature before it is collected. This is done by leading water from the site of collection through a copper coil immersed in running water, or, preferably, an ice bath. Then lead into the sample bottle as described above in case of cold water.

Both a gallon bottle as well as 250 mL glass-stoppered bottles are used to collect samples from a tank, pond, or river. These bottles are provided with two hole rubber stopper carrying glass inlet and outlet tubes. The inlet tube is extended to the bottom of the bottles and the outlet tube is extended only to the bottom of the stoppers. The outlet tube of the sample bottle is now connected with the inlet tube of the gallon bottle. Now immerse the bottles in the water to the required depth, and apply suction to the outlet of the gallon bottle.

(b) Procedure—The first steps are usually performed in the field. After removing the stopper from the bottle, immediately start the analysis in the bottle in which the sample was collected. All reagents are added from a burette by dipping it well under the surface of the sample. In this process, some sample may overflow. The overflow may also occur when the stopper is inserted after the addition of each reagent.

Nitrites, sulphides, sulphites, ferrous compounds and organic matter etc. are first oxidised by adding 0.7 mL of conc H_2SO_4 and then 1 mL of $KMnO_4$ containing 6.32 g per litre. This is approximately 0.2 N. Insert the stopper and shake the bottle well several times. If $KMnO_4$ is insufficient, add more of it. After the colour has persisted for 20 minutes, the excess of $KMnO_4$ is destroyed by adding 1 mL of 2.17 N potassium oxalate solution, which can be prepared by dissolving 20 g of CP potassium oxalate in one litre of pure distilled water.

In the next step dissolved oxygen is readily absorbed by manganous hydroxide. For this, a filtered manganous sulphate solution which contains 480 gms of $MnSO_4 \cdot 4H_2O$ or 400 gms of $MnSO_4 \cdot 2H_2O$ per litre, is first prepared. An alkaline KI solution is also prepared by dissolving 700 gms of KOH and 150 gms of KI in water and diluting to one litre. Now add 1 mL of manganous sulphate solution and 5 mL of alkaline KI solution to the sample and mix well. As a result, manganous hydroxide is precipitated which will settle down on standing.

Now add 1 mL of conc H_2SO_4 and shake well. The dissolved oxygen will liberate free iodine from the KI present. The rest of the determination is performed in the laboratory.

Transfer 200 mL of the contents of the bottle to a 500 mL conical flask and titrate it against 0.025N sodium thiosulphate solution. Add 0.5 mL of 0.5% starch solution and complete the iodometric titration to the disappearance of the blue colour.

Calculation –

$$\text{mL Sodium thiosulphate} \times \text{Normality} \times 0.008 \times \frac{10^6}{\text{Vol. of sample (mL)}} = \text{ppm dissolved oxygen}$$

In the titration of 200 mL of the sample using 0.025 N sodium thiosulphate, this is

mL sodium thiosulphate ≡ ppm dissolved oxygen

Polarographic method—Dissolved oxygen is readily reduced at the dropping mercury electrode. An aqueous solution saturated with air exhibits two polarographic waves which are attributed to oxygen. The first wave is obtained as a result of reduction of oxygen to peroxide, and the second as a result of further reduction of peroxide into water.

$$O_2 + 2H^+ + 2e \rightleftarrows H_2O_2$$

$$H_2O_2 + 2H^+ + 2e \rightleftarrows 2H_2O$$

Thus oxygen is polarographically active and is reduced (first to H_2O_2 and then to H_2O) in water at 0.05 V and –0.94 V. The polarograms given by oxygen serve as a means of determining the dissolved oxygen in water. Thus in polarographic analysis, usually nitrogen is passed through the solution for several minutes, just before the determination. In addition to dropping mercury electrode, O_2 can be reduced at several other electrodes in aqueous solutions if a small –ve voltage is applied. The magnitude of current passing through the solution can be determined by the rate of diffusion of O_2 to the electrode.

The polarographic method is, however, not much used in the DO analysis of domestic or industrial waste waters because of the fear of poisoning of the dropping mercury electrode by the impurities present in the sample water.

Membrane electrode method—This method is suitable for the DO analysis and consists of a **Mackereth Oxygen Cell** in which two metal electrodes of Ag and Pb are dipped in a saturated solution of $KHCO_3$, which is separated from the sample test solution by using a polyethylene membrane (0.06 mm thick). In this manner, a galvanic cell can be plugged to a pH meter to get the direct DO reading in mg/litre (The 0-14 pH scale in pH meter becomes 0-14 mg/litre DO). The current is measured (a) For the sample (b) For a standard (Sample after saturation with air) and (c) For a blank (Sample after treatment with Na_2SO_3 to expel O_2).

Reactions at Ag electrode - (negative electrode)

$2H_2O + O_2 + 4e \rightarrow 4OH^-$ $\qquad$ $Pb + 4OH^- \rightarrow PbO_2 + 2H_2O + 4e$

Reaction at Pb electrode - (positive electrode)

$$2Pb + 4OH^- \rightarrow 2Pb(OH)_2 + 4e$$

The optimum value for good quality water has been 4–6 mg/litre of DO, which is able to maintain aquatic life in a water body. If DO values are somewhat lower than this value, then the water is expected to be polluted.

BIOCHEMICAL OXYGEN DEMAND (BOD)

Excessive nutrients, such as nitrates and phosphates, commonly originate in domestic sewage, runoff from domestic fertilizers, waste material from animal feed lots, packing plants etc. These nutrients are responsible for water pollution primarily because they stimulate the growth of micro-organisms which then increase the **Biochemical Oxygen Demand (BOD).** ***Eutrophication*** *(meaning well nourished or enriched) is a natural process in many lakes and ponds which have a rich supply of nutrients.* It also occurs as a part of aging process in lakes and ponds, as nutrients accumulate through natural succession. **Eutrophication,** however, becomes excessive because of abnormally high amounts of nutrients from sewage, fertilizers, animal wastes etc. entering into streams, lakes or ponds. This causes excessive growth or **bloom** of micro-organisms and aquatic vegetation.

Most **secondary sewage treatment plants** are capable of precipitating solids and inactivating most bacteria in the domestic sewage, but they are incapable of removing basic nutrients such as nitrates, phosphates, ammonia, nitrogen etc. These nutrients stimulate algae growth and lead to **plankton bloom.** The bloom of green algae create problems of oxygen supply in water. When they exist under abundant sunlight, they contribute oxygen to water through the process of photosynthesis. But under conditions of prolonged cloudiness, they start decaying and consume more oxygen than they produce. This causes decrease of oxygen in water. Moreover, bacterial decomposition of organic matter also requires oxygen and with heavy loads, the oxygen content of water may decrease to such an extent that most fish can not survive in water. Due to decrease in oxygen content of water by bacterial decomposition or planktonic blooms, the conditions in water become anaerobic as a result of which breakdown products get reduced instead of being oxidised. Thus many of such products, *e.g.*, H_2S produce offensive odours and tastes.

We thus conclude that there is a close relationship between organic matter and dissolved oxygen in water. Thus water pollution is measured by biochemical oxygen demand (BOD), which is a standardized measurement of the amount of oxygen required by micro-organisms (seed) to cause the break down or decomposition of organic matter in water sample over a period of 5 days at 20°C. The result is called the 5 day BOD and is expressed in milligrams oxygen per litre of water (mg/litre) or in ppm. The pure drinking water, on the monthly average, should have 5 day BOD in the range of 0.75–1.5 mg/litre. BOD value of raw sewage runs from 200–400 mg of oxygen per litre of water (200-400 ppm). BOD values of several hundred milligrams per litre indicate **strong sewage.** In fact, drinking water should have BOD less then 1 ppm.

BOD of say, 70 mg/litre of polluted water indicates that the biodegradation of organic matter ... litre of sample consumes 70 mg of oxygen.

$$[CH_2O] + O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$$

The selection of micro organisms (seed) is very important and the results are obviously ... ducible. **It should be noted that BOD is an indicator and not a pollutant.** It measures any ... that can be consumed by micro-organisms using O_2 or any material attacked under the conditions of ... tests. The substances decomposed in the BOD test may be food used by the micro organisms or ... chemicals that are readily attacked by O_2, perhaps with the help of enzymes released by microorganisms ... These chemicals are sulphates, sulphites, sulphides, ferrous ions and some easily oxidizable compounds ...

BOD values are very important, when they signify :

(a) That oxygen supply dissolved in water will be so greatly reduced that fish no longer survive ... water. (b) That conditions for the propagation of dangerous bacteria exist.

CHEMICAL OXYGEN DEMAND (COD)

Although BOD test indicates the amount of total organic matter, there are so many drawbacks ... compensate them **Chemical Oxygen Demand (COD)** test is carried out. It is an index of the total ... content of water oxygen demanding substances in water. COD is readily measurable parameter for ... and industrial waste studies and control of water treatment plants. The method of measurement of ... depends upon the chemical oxidation of the sample with a strong chemical oxidising agent, ... potassium dichromate ($K_2Cr_2O_7$) which is capable of oxidising all the organics. The results of the ... are usually expressed in terms of oxygen that would be needed (because oxygen is not itself used ... oxidise the contaminant to the same final products obtained with the standardized analysis. COD ... *therefore, be defined as the amount of oxygen required by organic matter in a sample of water ... oxidation by a strong chemical oxidising agent such as $K_2Cr_2O_7$. It is expressed as ppm of oxygen ... from a $K_2Cr_2O_7$ solution in two hours.*

A known amount of $K_2Cr_2O_7$ is added to a measured amount of the sample and the mixture is ... with concentrated sulphuric acid. After boiling, the amount of unreacted dichromate ($Cr_2O_7^{2-}$) is determined ... by titration against a standard ferrous ammonium sulphate (Mohr's salt) solution using ferroin as ... indicator. Sometimes Ag_2SO_4 is added in the oxidation process, which catalysis the oxidation of ... chain aliphatic compounds, aromatic compounds and pyridine. $HgSO_4$ is also added to tie up Cl^- in ... soluble complex and thus prevents its interference.

So the actual oxidation may be carried out by boiling 5-50 mL sample in a conical flask of 2... capacity with 10-20 mL 0.25 N $K_2Cr_2O_7$ in 18 N H_2SO_4 in presence of 1g. $HgSO_4$ and 1g. Ag_2SO_4 ... cooling excess of $K_2Cr_2O_7$ is titrated with 0.1 N ferrous ammonium sulphate in 8N H_2SO_4 using 1-2 ... of ferroin as an indicator.

The difference between the dichromate originally present (added) and the dichromate remaining ... reacted gives the amount of dichromate used for the oxidation of organic matter.

Chemical oxygen demand (COD) has been found to be more scientific than the biological oxygen demand (BOD). It should be noted that it is not necessary for the COD values to correlate with B... values. Textile wastes, paper mill wastes and other wastes having higher levels of cellulose have ... found to have considerably higher COD values than their BOD values, because of the fact that cellulose ... is not readily attacked in BOD test. Distillery and refinery wastes often have higher BOD values ... COD values unless COD measurement is specially modified. **The BOD of a given water supply decreases faster than its COD value.**

The BOD value approximates the amount of oxidisable organic matter. So it is used to measure ... of water pollution and waste strength. COD is a poor measure of organic matter, as oxygen is ...

...ed in the oxidation of inorganic matter (such as nitrates, sulphates, reduced metal ions etc.) as ...is some organic materials such as benzene, pyridine etc.

BOD values are useful generally in process design and loading calculations, measurement of treatment ...ency and operation, stream pollution control and in determining the self purifying capacity of a ... COD is important in management and design of treatment plant because of its rapidity in deter-...ation. It is used in calculating the efficiency of treatment plants and proposing standards for discharging ...ic effluents in various types of water streams.

BOD test is usually influenced by the following factors :

(a) Type of microorganism (seed). (b) pH value of water. (c) Presence of toxic materials. (d) Nitri-...tion process. (e) Reduced mineral matter.

COD test is not much influenced by these factors.

BACTERIOLOGICAL EXAMINATION OF WATER

...BACTERIOLOGICAL TEST

Water may contain bacteria which are very small organisms. Some bacteria are harmful and called ...pathogenic bacteria, while some others are harmless and are known as **non - pathogenic bacteria. Patho-...genic bacteria** present in water are responsible for causing diseases like cholera, typhoid, dysenteries etc. ...is therefore extremely important to treat the public water supply for removing these pathogenic bacteria, ...if they are present. It is, however, very difficult to isolate pathogenic bacteria in the laboratory. Since ...isolation of pathogenic bacteria is time consuming as well as difficult, simple tests are performed to ...determine the possible presence of intestinal organisms, which are known as **coliform group of bacteria,** ...some of which may also be non - pathogenic. The presence of intestinal bacteria also indicates the presence ...of pathogenic bacteria. **Coliforms are good indicators of pollution**. Hence, the presence of pathogenic ...bacteria can be detected by testing for the coliform group of bacteria.

Escherichia coli (E. coli) is the most common bacteria in the coliform group. These bacteria are ...harmless but their presence indicates that pathogenic bacteria may also be present. E. coli germs are ...discharged in very large numbers with the faeces.

There are two important bacteriological examinations.

(1) Total count test (2) E. coli test or coliform test

Total count test - In this test the sample of water with agar added to it, is placed in an incubator at 37°C for 2 days (48 hours) or at 37°C for one day (24 hours). The bacteria in water grow and form colonies which can be seen and counted. For potable water the total count should not be greater than 100 per mL of water.

E. coli test or coliform test - It has been observed that coliform in lactose medium undergo fermen-...tation at 37°C within 48 hours with the formation of gas. E. coli test is performed in three stages.

(a) Presumptive test - In this test, samples of water are placed in sterile tubes and lactose is added. The tubes are placed in an incubator for 24 hours at 37°C. If gas is evolved, the test is positive and indicates the presence of bacteria. if no gas is formed, the process is again examined at the end of 48 hours. If still no gas is evolved, the test is negative.

(b) Confirmed test - (i) When a sample of water is positive in the presumptive test, a small amount of lactose broth is transferred to another fermentation tube containing green lactose bite. If gas is formed, even after 48 hours, the test is positive and indicates that water is unfit for drinking.

(ii) A small portion of sample of water is taken on a plate containing endo or eosin - methylene - blue agar. The plates are kept at 37°C for 48 hours. The result is positive, if colonies are seen. A completed test is then carried out inorder to establish the presence of E. coli group of bacteria.

(c) Completed test - This test is performed by adding the water sample to lactose broth fermentation tubes and agar tubes. The tubes are placed in an incubator for 24 to 48 hours at 37°C. If gas is formed

STABILISATION

The main objective in the sewage treatment is the ***stabilisation of its organic matter.*** *The break of organic matter by bacterial action into simple substances that do not decompose further is* ***stabilisation*** *and may be brought about by* ***aerobic or anaerobic bacteria.***

Stabilisation by aerobic bacteria is much more rapid than anaerobic bacteria, and is not accom by unpleasant odours. Anaerobic bacteria are used to stabilise organic matters which have been from the sewage by **sedimentation**, and the process is known as **sewage digestion.** Stabilisation aerobic bacteria requires much more time than the aerobic process and is subject to serious upset. **anaerobic sludge digestion** does not proceed to complete stability, but to a point where further position is so slow that no odour or other difficulties occur.

In addition to strictly aerobic and strictly anaerobic bacteria, there is also a group of bacteria as **facultative bacteria**, which can carry on their life processes under either aerobic or anaerobic con

PROPERTIES OF SEWAGE

The properties of sewage can be classified into three groups.

(a) Physical properties. (b) Chemical properties. (c) Biological properties.

(a) Physical properties - (i) Specific gravity - Specific gravity of sewage is almost equal to water.

(ii) Colour - Colour of fresh domestic sewage is earthy or grey. It has soapy or oily smell, giving offensive smell after 2 hours and is maximum after six hours, when it is called **stale sewage**

(iii) Turbidity - Normal sewage is usually turbid and it contains some matter which can be identified when the sewer is fresh. Such matter includes faecal matter or night soil, pieces of paper, plastics, cigarette ends, fruit and vegetable skins, vegetable debris, match sticks etc. Some solids in sewer are also in suspension. *Turbidity of water shows that some amount of solid matter is present in suspension.*

(iv) Solids - Sewage contains a very small amount of solid in comparison to huge amount of liquid. Liquid content of normal sewage is about 99.9% and the total amount of solid matter present as suspended or dissolved matter is only about 0.1% . It has been estimated that 2000 kg of sewage contains 1 kg of solids only. This solid normally includes 0.50 kg in dissolved form, 0.25 kg. in settleable form, 0.25 kg in suspension form. Sewage also contains organic and inorganic matter. Normally one litre of sewage have been found to contain about 100 parts of solids only, 30 parts of solids being in suspended form and 70 parts of solids in dissolved form. Out of 30 parts in solid form, 20 parts are organic and 10 parts are inorganic solids. Out of 70 parts in dissolved form, 25 parts are in organic and 45 parts in inorganic form. Generally inorganic solids present in sewage are not very harmful. Only suspended and dissolved organic solids are responsible for creating troubles in the disposal of sewage and so these require proper treatment. Inorganic solids present in the sewage include mineral matter such as dissolved salts, sand, grit, gravel, chlorides, sulphates etc. Organic solids present in the sewer include

(a) *Cellulose, cotton, fibre , sugar, starch etc. (All carbohydrates)*

(b) *Fats and oils from kitchens, garages, shops, laundries etc.*

(c) *Nitrogen compounds such as proteins and their decomposition products. Examples are from animals, fatty acids, hydrocarbons, urea etc.*

(v) Temperature - The temperature of sewage is slightly higher than ordinary water. As are closed, the bacterial activity increases because of which the temperature also increases (reaction).

(b) Chemical properties - Sewage contains complex organic matter derived from faeces, Organic matter may be presents in the form of nitrogen containing compounds and non - nitrogen containing compounds. Urea, proteins, amines etc are present as nitrogen compounds, while soaps, carbohydrates are present as non - nitrogenous matter. In addition to solids and liquids, sewage also

gases like H_2S, CH_4, NH_3 a
position of organic matter
alkaline in nature but it ge
and alkalies from bathroo
industrial wastes possesses
chemicals.

(c) Biological proper
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compounds into simple a
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gases like H_2S, CH_4, NH_3 and CO_2. These gases are obtained either from atmosphere or by the decomposition of organic matter present in sewage. Normally fresh sewage and treated or purified sewage is alkaline in nature but it gets acidic as it becomes stale (After 2 - 6 hours). Sewage also contains salts and alkalies from bathrooms, kitchens and industrial plants. It should be noted that sewage containing industrial wastes possesses unusual chemical properties because of the presence of large number of different chemicals.

(c) **Biological properties** - Sewage contains bacteria as well as other living microorganisms such as algae, fungi and protozoa. Bacteria in sewage carry out the processes of breaking the complex organic compounds into simple and stable compounds. Bacteria are present in the sewage in large number and depending upon their nature, they can be classified as pathogenic bacteria (which are harmful and responsible for causing a number of diseases) and nonpathogenic bacteria, which are harmless. Pathogenic bacteria in sewer come from the discharges of persons and animals suffering from various diseases. The various important sources of bacteria are faecal matter or night soil, urine, discharges from stables, slaughter houses, industrial wastes etc.

Depending upon their action, the bacteria are classified as aerobic bacteria, anaerobic bacteria and facultative bacteria. For their existence and development, the aerobic bacteria require light and free oxygen, while anaerobic bacteria do not require light and free oxygen. The facultative bacteria are capable of existing in the presence as well as in the absence of oxygen, but they grow in plenty in the absence of air. In the study of sewage treatment, only two types of bacteria, namely aerobic bacteria and anaerobic bacteria are very important. Aerobic bacteria live in the presence of oxygen dissolved in water or free oxygen, while anaerobic bacteria live and carry on their activities in the absence of free oxygen.

Bacteria are microscopic unicellular organisms. They get food through ferments, called **enzymes.** These enzymes surround the cell structure of bacteria and they are produced by living cells. Enzymes act as catalysts. **Enzymes may be intracellular and extracellular. Intracellular enzymes** work inside the cell and they are responsible for maintaining the cell nucleus. **Extracellular enzymes** filter out through the wall of cell and they act on organic matter and convey it to the inside of cell. The action of enzyme is specific, that is, a specific enzyme can act on a particular substance only. Enzymes act as organic catalysts and so they are free after each bio-chemical reaction for repetition of the process.

Enzymes are found to be sensitive to various environmental factors such as pH, temperature, concentrations, metallic ions etc. Enzymes are capable of catalysing many types of reactions such as oxidation, reduction, hydrolysis, decarboxylation, deamination etc.

The decomposition of sewage takes place in two stages.

(1) **Aerobic decomposition. (2) Anaerobic decomposition.**

(1) **Aerobic decomposition** - Sewage contains organic matter, waste products, water etc. Aerobic bacteria convert this matter to nitrogenous, carbonaceous and sulphurous compounds, when oxygen is present in plenty or when it is made available by the **putrefaction process. Aerobic decomposition is also known as oxidation because it takes place in the presence of free oxygen or dissolved oxygen in sewage water.** During oxidation, the complex organic matter is broken down into simpler stable compounds. With the supply of more oxygen, these stable compounds are further decomposed and the end products of oxidation include carbon dioxide, nitrites and nitrates. Aerobic bacteria produce gases which are not offensive in odour. ***It should be noted that :***

(1) The organic matter present in the sewage can be stabilised by converting it into inorganic form by aerobic decomposition or oxidation. (2) The oxidation is done artificially by adding oxygen or green algae in oxidation tanks which produce oxygen in photosynthesis. (3) Aerobic action takes place when sufficient amount of free oxygen is available for the bacteria. (4) The dirty sewage water contains all mineral elements essential for the healthy growth and development of algae, e.g. nitrogen, phosphorus, sulphur and potassium. In dirty water these mineral elements are present in the form of organic matter. (5) To be utilized by algae, these substances must be oxidised to harmless substances such as CO_2, NH_3, NO_3, PO_3, SO_4 etc. This is done by algae and aerobic bacteria. Algae produces oxygen for bacteria (by photosynthesis) and bacteria oxidise the complex organic compounds into stable inorganic form. (6)

In self purification of streams, free oxygen is dissolved at the water surface and becomes avail… aerobic bacteria. (7) Oxygen may also be obtained from easily decomposable compounds, such as … and nitrates. (8) In sewage treatment plants oxygen is furnished by (a) Allowing sewage to trickle … the pores, as in trickling filters, and (b) Blowing air through a mixture of previously activated sludge … sewage, or setting up a strong agitation so that much oxygen is dissolved at the surface. Both … processes may also be used in combination as in activated sludge treatment method.

Treatment plants working on the oxidation principle are aeration tanks, contact beds, … sand filters, trickling filters and oxidation ponds.

(2) Anaerobic decomposition - Fresh sewage contains oxygen to the extent of about 2 … The aerobic bacteria react on organic matter present in the sewage and the available oxygen is … by them. When the aerobic bacteria die, anaerobic bacteria start their activity with the little … oxygen available in the organic matter. These bacteria attack complex organic compounds and … them into solids, liquids and gases. Anaerobic decomposition is also known as **putrefaction** and … products of putrefaction include black residue called humus, NH_3, CH_4, H_2S, CO_2, N_2, H_2 etc. The … produced in the process are very offensive in odour. ***It should be noted that :***

(1) Anaerobic bacteria grow in the absence of free oxygen and release energy. They get energy … various compounds which are decomposed by these bacteria. The decomposition takes place in a … of stages. The principal end products of decomposition of carbonaceous organic matter and nitrog… matter (proteins) are CO_2, CH_4, organic acids, NH_3, aminoacids, amides, indole and skatole. The … and skatole have most unpleasant odours. The sulphur compounds get decomposed into H_2S, merc… etc. which are also unpleasantly odourous. The unpleasant odour of sulphur compounds is notic… in the earlier stages of decomposition. Under carefully controlled sewage treatment conditions, the … from sulphur compounds may not be noticeable.

(2) Treatment plants which work on the principle of putrefaction are septic tanks, Imhoff tanks, … digestion tanks. The anaerobic decomposition is disordered and offensive. It is much slower than … decomposition. With respect to energy conversion it is, however, less efficient. For example, gluc… about 30 times more energy by aerobic decomposition than by anaerobic decomposition.

(3) Plants use the products of decomposition such as CO_2 or nitrates for producing chlorophyl… plants die they are decomposed by aerobic as well as anaerobic bacteria and thus the cycle goes …

(4) Fresh sewage does not have offensive odour. But after about 2 to 6 hours it becomes stale … and foul. Hence in sewage treatment, aerobic decomposition is encouraged by supplying oxygen … activity. Oxygen is supplied in the following ways.

(a) Allowing sewage to pass through porous medium and circulating air through the pores … trickling filters. (b) Adding activated sludge to fresh sewage and blowing air.

PURPOSE OF SEWAGE TREATMENT

There are several purposes of sewage treatment. Important ones are :

(1) *To render the sewage inoffensive as far as nuisances are concerned.*

(2) *To prevent destruction of aquatic life, e.g., fish and other wild life.*

(3) *To render or eliminate the danger of contaminating water supplies, bathing areas and …*
In so far as these ends are accomplished, stream pollution is prevented.

There are, however, a number of problems which have to be solved during sewage treatment… example :

(a) *Water bodies, such as rivers, ponds or lakes, which receive sewage (raw or treated) … of self purification.*

(b) *Water to be used for public purposes will also require treatment of some sort, if it is … from surface sources. Such treatment can take care of considerable amount of pollu…*

(i) *The sewage treatment as well as water treatment cost should be reasonable, but the degree of treatment directly affects the cost.*

METHODS OF SEWAGE TREATMENT

The impurity in a particular sewage, or in other words, the amount of treatment required, is usually based on one of the two basis :

(1) *The amount of suspended solids.*

(2) *The biological oxygen demand (BOD) which measures the amount of impurities by the amount of oxygen required to oxidise it.*

The treatment procedures are generally divided into three groups :

(1) Primary treatment or mechanical treatment. (2) Secondary treatment or biological treatment. (3) Tertiary treatment or advanced biological, chemical and physical treatment.

In brief use of nacks and screens and of skimming tanks and grit chambers, is called **preliminary or preparatory treatment.**

Removal of settleable solids is called **primary or mechanical treatment.**

Removal of solids with the help of living organisms is called **secondary or biological treatment.**

The combination of primary and secondary treatment constitutes **complete treatment.**

Further purification of waste water by advanced biological, chemical and physical processes and also the recycling of waste water is the aim of **tertiary treatment.**

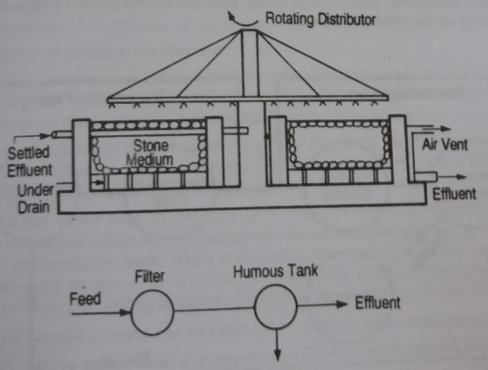


Fig. 1. The biological filter.

(1) **Mechanical treatment** of removing solids consists in passing the sewage through screens, filters, grit chambers (shallow rectangular tanks in which the velocity of flow is checked so as to cause the grit to settle down, carrying some of the organic matter with it), sedimentation basins and trickling filters etc. In some installations, the various methods are employed in series.

Infact, primary or mechanical treatment includes screening, grinding, flocculation or coagulation and sedimentation.

In **screening** the larger suspended and floating materials such as paper, rags, wooden pieces, wires etc. are removed. Screening system consists of two units. The first unit (coarse screen) consists of metal bars or heavy wires spaced 25-40 mm apart, and the second unit consists of fine screens. The ... that are removed by screening are usually **incinerated.**

The **grinding** is carried out in grinders of rotating screens with cutting teeth. These are used to chop the solid materials to size smaller than 6 mm.

Chemical treatment precipitates the solids by **flocculation or coagulation.** The coagulates settle down rapidly. The coagulants of importance are ferric sulphate or chloride or aluminium sulphate with lime. The coagulates are then removed either by **sedimentation,** the process by which the suspended solids are removed by gravity settling, or by **filtration.**

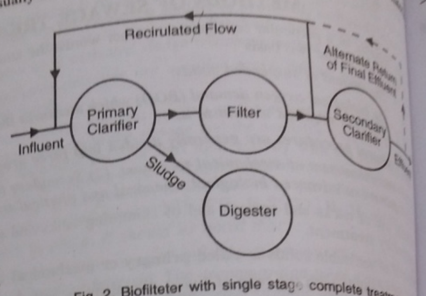


Fig. 2. Biofilteter with single stage complete treatment.

The sedimented solids left behind from the settling tank are piped to a **sludge digester** ... organic matter is decomposed in the absence of air. One of the decomposition product, *i.e.*, meth... can be frequently used to meet upto 90% power needs of the primary treatment plant.

A report by **American Chemical Society** has indicated that primary or mechanical treatment ... about 60% of the total suspended solids, 35% BOD, 30% COD (chemical oxygen demand), 2... nitrogen and about 10% of the total phosphorus.

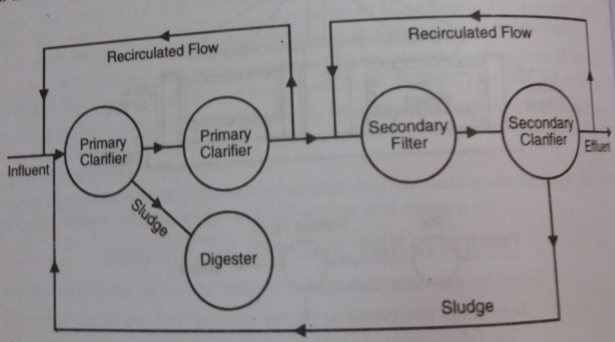


Fig. 3. Biofilteter with two stage complete treatment.

Important features of preliminary or mechanical treatment.

(1) *Waste water contains floating suspended solids such as rags, wood, metal, plastics ... are necessary to be removed because they interfere with the sewage treatment ... mechanical equipment.*

(2) *The main objectives of preliminary treatment are to remove (a) Coarse suspended ... matter, by means of screening (b) Grit, ie, sand, broken glass etc, in grit chambers ... Grease and oily substances by floatation in skimming tanks.*

(3) Sewage admitted to sewage treatment plants and pumping stations should be effectively screened inorder to protect the machinery in the plant and to prevent difficulties in subsequent stages of treatment. Screening is also necessary when raw sewage is discharged into water bodies such as rivers, streams, seas etc, without treatment.

(4) Screens are used for the removal of certain materials such as pieces of wood, plastics, paper, floating debris, rags etc present in the sewage.

(5) Depending on the clear spacings between flats, the screens are classified as coarse screens (Above 50 mm), medium screens (20 – 50 mm) and fine screens (20 mm). Screens can be operated manually as well as mechanically.

(6) Sewage contains inorganic matter such as sand, broken glass or crockery etc. These enter sewage from washings, kitchens etc. This grit is necessary to be removed, otherwise it will create problem in sludge digestion, because it combines with organic matter present in the sludge. It also causes wear and tear on pumps. Finer particles of grit are removed in detritus tanks and coarse particles of grit are removed in girt chambers.

(7) Grit is disposed off by filling up low lying areas. It forms a good manure for growing crops.

(8) Sewage also contains grease and oil, which enter sewage from hotels, kitchens, soap and candle factories, garages etc. They produce foul odour when sewage is directly discharged in water. They also retard aeration as a result of which anaerobic conditions are caused. They clog the trickling filters and interfere with the working of bacteria. They are also not easily digested in sludge digestion tanks. Hence, they are also necessary to be removed. Greases and oils are removed in skimming tanks.

(9) The screenings are generally disposed off by burial in the ground, disintegration, incineration and as fertilizer. The process of incineration has proved to be most effective for large works.

Important features of primary treatment :

(1) The primary treatment to sewage consists of mainly the sedimentation process to remove suspended organic solids. Chemicals are sometimes added in primary clarifiers inorder to assist the removal of finely divided and colloidal solids or to precipitate phosphorus.

(2) The main objectives of sedimentation are : (a) The finely divided suspended solids are settled down by the sedimentation process. (b) Sedimentation removes 80 – 90% of settleable solids. (c) It reduces the strength of sewage by 30 – 35%.

(3) Sedimentation tanks may be primary or secondary. When a sedimentation tank is used for settling suspended solids before biological treatment (soon after the grit chamber), it is called primary sedimentation tank. When a sedimentation tank is used for settling suspended solids after biological treatment, it is known as secondary sedimentation tank. When chemicals are used to increase the settling of suspended solids, the process is known as chemical precipitation.

(4) The liquid sewage coming out of tanks after sedimentation process is known as effluent.

(5) The thick viscous liquid settled at the bottom of the tank is called sludge.

(6) Sedimentation tanks may be horizontal flow type or vertical flow type. The sedimentation tanks used for treatment of sewage are the same as that used for water supply.

(7) The floating matter is periodically removed and the sludge from the bottom is removed by hand cleaning, mechanical cleaning or hydraulic cleaning.

(8) Sedimentation of sewage can be assisted by adding certain chemical substances known as coagulants. Coagulation of sewage is similar to that of water. Coagulants react with colloidal matter in sewage and form what is known as floc. The latter enmeshes the smaller particles and grows in size to form larger particles. These particles settle down.

(9) Coagulation or chemical precipitation is done in two stages (a) The chemical is added to the sewage and agitated briskly inorder to mix the chemical well. (b) The chemical mixes well

intimately with the sewage when slow agitation of the mixture for a longer period is ... out. The particles grow in size and settle down. The process is called flocculation.

(10) Commonly used coagulants in sewage treatment are alum, chlorinated copperas, lime, ... sulphate, ferric chloride, sodium silicate, sulphur dioxide etc.

(11) Advantages of coagulation are : (a) Sedimentation by coagulation is more effective. (b) ... colour and turbidity are much reduced. (c) The process is simple in operation. (d) Coag... tanks require less space than the plain sedimentation tanks.

(12) Main disadvantages of coagulation are : (a) Chemicals destroy the bacteria that dige... sludge. (b) The cost of sedimentation is more. (c) Skilled supervision is required. (d) La... quantity of sludge is produced which requires efficient disposal.

(13) Coagulation is not necessary when biological treatment is resorted to. Since biological ... ments are employed now a days for purification of sewage, the process of coagulation is ... much used now.

(2) **The secondary or biological treatment** involves particularly the **trickling filters and acti... sludge processes.** Purification by treatment on **trickling filters** depends primarily on absorption ... as adsorption of both soluble and suspended matter from the waste water into and onto zoogloeal ... The latter develop and proliferate on the surface of the filtering medium over which the water tric...

As a result of flow of waste water through the beds, decomposition takes place and soluble substances as well as sludge forming solids are synthesized. Bacteria, protozoa, fungi and other living organisms are responsible for these decomposition and oxidation processes. These bacteria decompose the dissolved organic materials and absorb nutrients and energy. Any solid matter present is piped to a **settling tank** which is then transferred to a **sludge digester,** where it is decomposed by micro-organisms. The treated fluid is then **chlorinated** and discharged into the water systems.

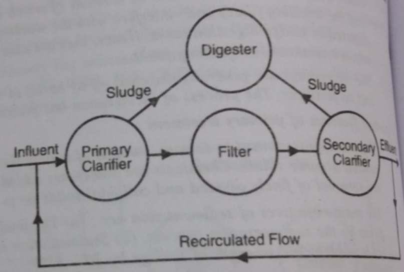


Fig. 4. Aerofilter with single stage treatment.

Activated sludge (settled out of sewage previously agitated in the presence of abundant oxygen) provides one of the most effective meth... for removing both suspended and dissolved substances from the sewage and somewhat more popular th... **trickling filters.** In this process biologically active growth are continuously circulated through orga... waste in the presence of oxygen. The activated sludge contains aerobic micro organisms which digest ... raw sewage. Some activated sludge from the previous run is introduced into the raw sewage and a... blown in only in the amount needed. Aeration activates the sludge particles so as to develop an a... culture of aerobic organisms.

The disposal of the solids removed by **secondary treatment** plants depends upon the local condi... In some cases they are buried, burned or sold as fertilizer material after filtering and drying. The liq... remaining after the removal of the solids are usually chlorinated to destroy harmful pathogenic bac... and then discharged into nearby streams. The drying of the sludge is carried out on sand beds ... dewatering the sludge. The dried sludge can be **incinerated or subjected to compositing.** It can als... used in sanitary land fills alongwith other refuse.

Important features of secondary or biological treatment :

(1) *Secondary or biolog... processes. The efflu... matter originally pr... mentation tanks an... or colloids is carri...*

(2) *The main function... sewage into stable...*

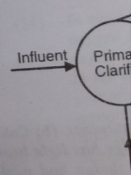
(3) *As seen above, se...*

(4) *The various filter... are contact beds, ... removes finely d...*

(5) *In activated slu... added to the ra... and colloidal m...*

(6) *The matter whi... called effluent... seas etc. The e... a natural drai...*

(7) *In secondary ... organic matte... form by aero...*



Important feat...

(1) *The ac... Now v... same. ... of sew...*

(2) *The a... allow... weir ...*

(3) *The ... activ...*

(1) Secondary or biological treatment includes processes such as filtration or activated sludge processes. The effluent from primary clarifiers contains about 45–50 % of unstable organic matter originally present in the sewage. Larger solids are removed by settlement in the sedimentation tanks and organic matter present in the sewage in the form of solution, suspension or colloids is carried away by effluent from the settling tanks.

(2) The main function of secondary treatment is to convert the remaining organic matter of the sewage into stable form by oxidation or nitrification.

(3) As seen above, secondary treatment mainly involves filtration and activated sludge process.

(4) The various filters which are commonly used for filtration of sewage in secondary treatment are contact beds, intermittent sand filters, trickling filters and miscellaneous filters. Filtration removes finely divided suspended matter.

(5) In activated sludge process, sewage is treated biologically. A part of the digested sludge is added to the raw sewage together with oxygen which promotes coagulation of the suspended and colloidal matter.

(6) The matter which settles down at the bottom after treatment is called **sludge** and the liquid is called **effluent.** The sludge is disposed off in many ways such as drying beds, dumping into seas etc. The effluent is also disposed off in many ways such as sewage farming, letting it into a natural drainage or sea.

(7) In secondary treatment remaining 45–50 % organic matter (suspended matter and a part of organic matter are removed by preliminary and primary treatments) is converted into stable form by aerobic and anaerobic bacteria.

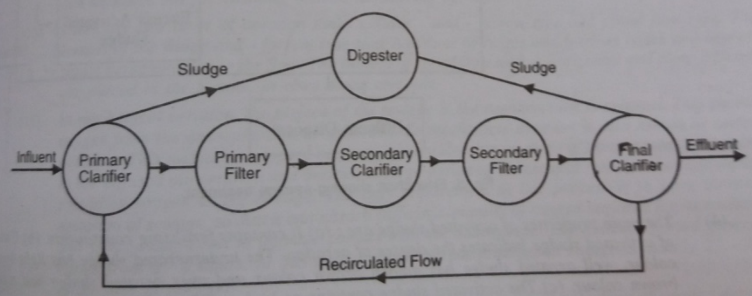


Fig. 5. Aerofilter with two stage treatment.

Important features of activated sludge process :

(1) The activated sludge process was first developed by Ardern and Lockett (1914) in England. Now various modifications have been made in the process but the fundamental principle is same. Activated sludge process is a biological sewage treatment process in which a mixture of sewage and activated sludge is agitated and aerated.

(2) The activated sludge is subsequently separated from the treated sewage by sedimentation and allowed to go waste or returned to the process as required. The treated sewage overflows the weir of the settling tank.

(3) The activated sludge is obtained by settling sewage in the presence of excess oxygen. Thus activated sludge is that sludge which settles down after the sewage has been freely aerated.

and agitated for a certain time. The activated sludge is biologically active and contains a large number of aerobic bacteria and other microorganisms. When activated sludge is mixed with raw sewage saturated with oxygen, the aerobic bacteria oxidise the organic matter and promotes coagulation and flocculation. They also convert the colloidal and suspended solids into settleable solids.

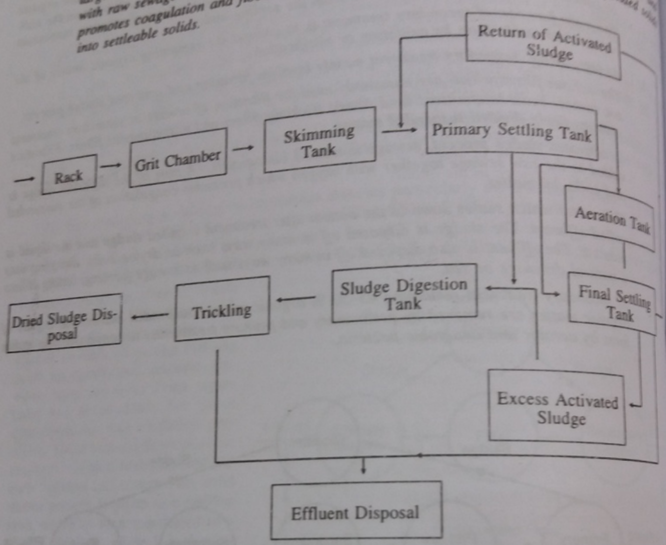


Fig. 6. Flow chart showing sewage treatment.

(4) *The main properties of activated sludge are : (a) It contains fertilising constituents. (b) Colour of activated sludge indicates the degree of aeration. The underaerated sludge has light brown colour, well aerated sludge has golden brown colour and over aerated sludge had mud brown colour. (c) The activated sludge contains as high as 95 to 97% of water.*

(5) *The activated sludge is mixed with raw or partially treated sludge. In activated sludge process sewage is first given primary treatment. When the sludge is mixed with sewage properly in presence of sufficient amount of oxygen, bacteria present in the activated sludge multiply rapidly as a result of which organic solids present in the sewage are readily oxidised and suspended as well as colloidal matter coagulate and they form readily settleable precipitate. After the settlement of this precipitate, the effluent is clear as well as sparkling. The effluent contains low amount of organic matter and it is generally not given any further treatment except chlorination. A part of the settled sludge is sent for recirculation and the remaining part is transferred to sludge digestion tanks. The digested sludge is not only harmless but also creates no nuisance.*

(6) *The following operations are made in activated sludge process.*
(a) The raw sewage is given primary treatment in settling tank. The detention period is

1 - 1.5 hours. (b) The sewage is then mixed with the required quantity of activated sludge and the mixed liquor containing activated sludge and effluent is aerated or agitated in the aeration tank for 4 - 10 hours according to the degree of purification needed. (c) The aerated mixed liquor is then sent to the secondary clarifier or final settling tank, where sludge is allowed to settle. Settled sludge is the activated sludge and a part of it is sent for recirculation. The extra or remaining activated sludge is transferred to sludge digestion tank and then to sludge drying beds for further treatment. (d) The effluent is disposed off.

(7) Some important advantages of activated sludge method are : (a) Gives clear sparkling treated liquid. (b) The effluent is free from bad smell or odour. (c) The degree of purity can be varied as required. (d) No trickling filter flies. (e) Small loss of head in the process.

(8) Some disadvantages of the process are : (a) Skilled supervision and constant check on the return sludge is necessary. (b) The process is not suitable in case of some industrial wastes. (c) Large volume of sludge presents difficulty in disposal. (d) The process gets upset when there is a change in the quality or quantity of the sewage.

(9) The success of activated sludge process depends mainly on the aeration provided. Three processes are generally employed for aeration of activated sludge. These are : diffused air aeration, mechanical aeration and combination of diffused air and mechanical aeration. In diffused aeration method, compressed air is passed through the sewage by plate or tube air diffusers. Plate diffusers are made from fused crystalline alumina or high silica sand. Plates are generally square in shape, measuring 30 cm x 30 cm and they are usually 25 mm thick. The plate has holes through which air is blown. Tube diffusers are made from crystalline alumina about 600 mm long with internal diameter of 75 mm and thickness of wall equal to about 15 mm. It is suspended into the sewage. The aeration period generally varies from 3 to 6 hours. The tubes can be taken out for cleaning without dewatering the tank.

(10) There are two types of aeration tanks - Ridge - and - furrow type and spiral flow type. The bottom of the Ridge and - furrow type tank has rows of ridges and furrows (rises and depressions) perpendicular to the flow. The bottom of spiral flow tank is horizontal and plate diffusers are placed in the bottom, in rows along one side.

(11) In mechanical aeration, the surface of the sewage in the aeration tank is agitated. This enables oxygen from the atmosphere to be absorbed. So mechanical aeration is also known as surface aeration. This method is adopted because, of considerable wastage of compressed air supplied in the diffused air aeration and because a large potion of air escapes through the tank without providing oxygen to the sewage. The only requirement in this process is to have thorough agitation of sewage, so that it can absorb sufficient quantity of oxygen required for its oxidation and sewage may come in intimate contact with the atmosphere. The aeration period generally varies from 6 - 8 hours. In this case, volume of return activated sludge is usually 25 - 30% of the flow of sewage.

(12) The volume of returned activated sludge which has to be added to the flow of sewage depends mainly on the desired removal of BOD. It is generally expressed as percentage of flow of sewage. The more the desired BOD removal, the more is the volume of activated sludge.

(13) In combined diffused aeration and mechanical aeration, the aeration of sewage is achieved by air diffusers as well as mechanical diffusers. Air diffuser plates are located at the bottom of the tank and the submerged paddles rotate in the direction opposite to that in which the compressed air rises up from the air diffusers. Paddles are rotated by means of a motor on a horizontal shaft and speed of motor is kept between 10 - 12 rounds per minute. The spiral motion set up in this way, provides the required aeration. In this combined method the aeration is efficient, detention period is much reduced (about 3 - 4 hours) and quantity of compressed air required is much less in comparison to the diffused air aeration.

(14) An excellent activated sludge, when overloaded becomes sick. As a result, sludge swells in volume. This process is called **sludge bulking**. Occurrence of sludge bulking shows the presence

of unsatisfactory conditions in activated sludge. Sludge bulking generally occurs because of following factors : (a) Accumulation of sludge at the bottom of aeration tank. (b) Under aeration of sewage. (c) Presence of harmful industrial wastes. (d) Sudden change in the character of sewage. (e) Detention of sludge in clarifiers for a long period.

(15) *Sludge bulking can be avoided by : (a) Chlorination of sewage. (b) Prolonged aeration. (c) Increasing the pH of sewage to 8.0 or above. (d) Adding lime. (e) Re - aeration of returned activated sewage. (f) Reducing sewage flow to aeration tank for some time. (g) Reducing the suspended solids in the sewage.*

(16) *The term sludge volume Index (SVI) is used to indicate the degree of concentration of sludge. It also indicates the physical state of the sludge. For determining SVI, a sample of sewage at the outlet end of the aeration tank is taken and the percentage of sludge in volume is obtained by keeping the sample in Imhoff cone for half an hour. The percentage of suspended solids in mixed liquor (MLSS) by weight is also determined. SVI is then calculated as follows.*

$$\text{SVI} = \frac{\text{\% of sludge (by volume)}}{\text{\% of suspended solids (by weight)}}$$

$$= \frac{\text{Settled volume of sludge (\%) in half an hour}}{\text{MASS (\%)}}$$

SVI is thus the volume in mL occupied by one gm of activated sludge after a settling period of half an hour. The desirable SVI is 100 or 100 mL per gram. SVI index varies from 50 to 150 mL per gram in diffused air aeration and from 200 - 300 mL per gm in case of mechanical aeration. High value of SVI indicates the favourable conditions for sludge bulking.

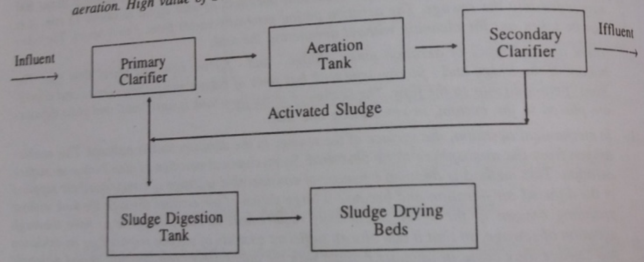


Fig. 7. Flow diagram of activated sludge process.

Primary treatment combined with secondary treatment can reduce the BOD to about 90%, COD to about 80%, total nitrogen to about 50% and total phosphorus to about 30%. The reduction in suspended matter has been estimated to be about 90%. Primary and secondary treatments are mainly developed to reduce BOD and suspended solids to about 90%. It should be noted that efficiencies of these processes are largely influenced by the temperature. Thus, secondary treatment is often inadequate during cold weather because microorganisms are not very active at low temperatures.

It should also be noted that the main difference between activated sludge method and trickling filters is that there is no medium to support the active zoogloeal slime in the active sludge process.

In recent years, certain detergents such as alkyl benzene sulphonates (**ABS**) have caused troublesome foaming in sewage disposal plants. This can be removed either by substitution by other but higher price detergents, or by modified aerobic microorganism attacks involving longer residence time than usual for sewage disposal plants. Defoaming agents, such as polyglycols can also be used with benefit.

In all advanced countries nearly 60-70% of domestic sewage receives the secondary treatment and usually involves aeration, activated sludge treatment, sludge digestion and trickling filter treatment.

(3) The aim of **tertiary treatment** is further purification of waste water as well as its recycling. The increasing costs of water supplies force us to recycle the waste water after purification. In an actual practice, in water scarce areas, waste water is recycled and utilized for a number of purposes. The most important purpose of tertiary treatment is an effective and efficient removal of pollutants than primary and secondary treatment and it can be applied at any stage of the total treatment, not necessarily after primary and secondary treatments. Tertiary treatment is the most advanced phase of sewage treatment which is provided to only 2% of domestic sewage. ***The main function of tertiary treatment is to decrease the load of nitrogen and phosphorus compounds present in the effluents by the following processes :***

(a) **Precipitation**—The effluent received after the secondary treatment is mixed with calcium oxide. This lime then reacts with phosphorus compounds in the waste to form insoluble calcium phosphate, which then settles down at the bottom of settling tank from where it can be filtered out.

(b) **Nitrogen stripping**—Nitrogen present in waste water is generally in the form of ammonia gas, nitrates and nitrites. Ammonia is highly undesirable in streams and lakes because it is extremely lethal to aquatic biota. Nitrogen eventually enhances **eutrophication,** which escalates rapidly when abnormally high amounts of nutrients from sewage, animal wastes, fertilizers and detergents enter the lakes or streams causing excessive growth of phytoplanktons and aquatic weeds.

The waste water containing ammonia is directed into a metal tower. As this water trickles downwards over a series of small plastic baffle plates, air is forced upwards through the effluent which thereby results in the removal of ammonia gas.

(c) **Chlorination**—The effluent from which nitrogen, phosphorus and dissolved organic matter is removed, is, then chlorinated to kill disease causing micro-organisms that might be present in waste water. The treated water is then discharged into rivers or lakes and can be used after normal chemical treatment.

The main purposes of chlorination are :

(a) To assist the formation of floc in the process of coagulation together with other chemicals. (b) To assist the process of treatment of some type of industrial wastes. (c) To control foaming in sludge digestion tanks. (d) To control fly nuisance because of sewage. (e) To increase the efficiency of sewage treatment plants. (f) To prevent activated sludge bulking. (g) To prevent corrosion of sewers. (h) To prevent spread of epidemics. (i) To reduce BOD, ponding in case of trickling filters and to remove oil, grease etc. (j) To thicken the sludge formed in activated sludge method.

The quantity of chlorine in ppm although varies from 20 ppm for raw sewage to about 5 ppm for completely treated sewage, but its amount depends upon various factors such as flow of sewage, contact period, quality of sewage etc. For better results, the amount of chlorine should be such that a residual chlorine of about 0.2 - 0.4 ppm appears after a contact period of 10 - 15 minutes. *In recent years there are various methods that have been used for advanced waste treatment. These are adsorption, chemical oxidation, desalination, chemical coagulation and filtration, oxygen ponds, Imhoff tanks etc.*

The process of **adsorption** is used to remove odours and tastes. Activated charcoal is the most effective universally employed adsorbing material. **The purpose of carbon adsorption** is also to remove dissolved organic components from the waste water. It can be achieved by passing the effluents through a tower packed with small particles of carbon. During the process of carbon polishing, the carbon particles get contaminated with dissolved organic matter. The process of **chemical oxidation** consists in oxidising the waste water by ozone or hydrogen peroxide so as to get pure water. The **desalination** is used to remove dissolved substances. Some of the various methods used for desalination are **ion exchange, electrodialysis and reverse osmosis.**

The **chemical coagulation and filtration** involves precipitation of solids by coagulation, which are then removed by filtration. The coagulants, such as ferric sulphate or chloride, aluminium sulphate (alum) with lime etc. react with suspended matter to form flocs, which settle out rapidly. After coagulation, filtration is achieved through sand filters or synthetic filters to remove flocs.

The individual or unit operations of sewage treatment are combined in various ways to create treatment processes. The use of suitable treatment processes, however, depends upon local requirements. A combination of unit operations for the treatment of combined sewage from a large community might include

(1) Grit chambers preceded by knocks if the chambers are mechanically cleaned. (2) Cutting screens. (3) Mechanically cleaned primary settling tanks with scum receivers or collectors. (4) Activated sludge unit. (5) Mechanically cleaned secondary settling tanks. (6) Vacuum filters for chemically conditioned sludge. (7) Heat driers or incinerators for partially dewatered sludge.

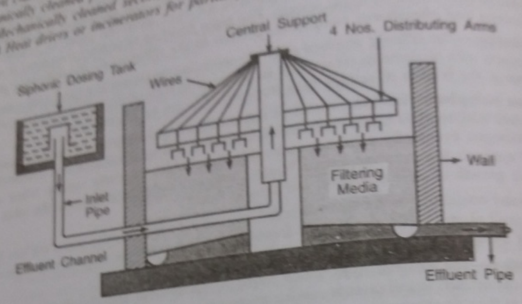


Fig. 8. Circular trickling filter.

A combination of unit operations for the treatment of sewage from a small community might include

(1) Bar screens. (2) Imhoff tanks. (3) Trickling filters. (4) Secondary settling tanks. (5) Sludge drying beds.

We have already seen that the best general yardstick of the strength of sewage are its BOD (bio-chemical oxygen demand), abridged BOD, and its contents of suspended solids.

REMOVAL OF PHOSPHORUS AND NITROGEN FROM WASTE WATER

Chemical processes – Chemical coagulants are generally used as a component of various levels of waste water treatment. There are two main functions of coagulants.

(a) *They assist in the coagulation and flocculation processes, inorder to maximise removal of very small solid particles of various compositions.*

(b) *They react and remove potential pollutant chemical species such as phosphorus in water.*

Turbidity in waste water is due to a mixed collection of solids having particles of different sizes, shapes and densities. Much of the suspended material, however, consists of colloidal material which settles too slowly to be removed. One of the functions of coagulants is to assist and speed up the settling process.

Alum and ferric chloride both are the sources of trivalent metal cations and their behaviour in waste water treatment is somewhat similar. For example, when alum is added to any water containing sufficient alkalinity, the hydrated Al^{3+} ion undergoes a series of hydrolysis reactions.

$$Al(H_2O)_6^{3+}(aq) + H_2O \rightarrow Al(H_2O)_5(OH)^{2+}(aq) + H_3O^+(aq) \quad \ldots(1)$$

$$Al(H_2O)_5(OH)^{2+}(aq) + H_2O \rightarrow Al(H_2O)_4(OH)_2^+(aq) + H_3O^+(aq) \quad \ldots(2)$$

$$Al(H_2O)_4(OH)_2^+(aq) + H_2O \rightarrow Al(H_2O)_3(OH)_3(s) + H_3O^+(aq) \quad \ldots(3)$$

$$Al(H_2O)_3(OH)_3(s) + H_2O \rightarrow Al(H_2O)_2(OH)_4^-(aq) + H_3O^+(aq) \quad \ldots(4)$$

The hydrolysis reactions involve successive deprotonation of the water of hydration surrounding the central metal ion. The extent of reactions depends on solution conditions, particularly the availability of