1.

$y_e =$ BOD of effluent $= 20$ mg/l.

Then $$y_s = \frac{Q_s y_s + Q_e y_e}{Q_s + Q_e} = \frac{1.2 \times 4 + 0.25 \times 20}{1.2 + 0.25}$$

$$= 6.759 \text{ mg/l.}$$

Now $$y_5 = L_0 (1 - 10^{-Kt})$$

$$6.759 = L_0 (1 - 10^{-0.13 \times 5})$$

From which $L_0 \approx 8.71$ mg/l ...(*i*)

Again, $(DO)_s =$ Saturation DO of stream at 20°C

$(DO)_e =$ DO of effluent $= 5$ mg/l.

$\therefore$ $$(DO)_{mix} = \frac{(DO)_s \times Q_s + (DO)_e \times Q_e}{Q_s + Q_e}$$

$$= \frac{(9.17 \times 1.2) + (5 \times 0.25)}{1.2 + 0.25} = 8.45 \text{ mg/l.}$$

$\therefore$ Initial DO deficit $= D_0 = 9.17 - 8.45 = 0.72$ mg/l. ...(*ii*)

(*a*) ***DO deficit at a point 20 km downstream***

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{20 \times 1000}{0.18 \times 60 \times 60 \times 24} = 1.286 \text{ days.}$$

Using Streeter-Phelps Equation (Eq. 9.5)

$$D_t = \frac{KL_0}{R - K}\left[10^{-Kt} - 10^{-R.t}\right] + D_0\, 10^{-R.t}$$

$$= \frac{0.13 \times 8.71}{0.3 - 0.13}[10^{-0.13 \times 1.286} - 10^{-0.3 \times 1.286}] + 0.72 \times 10^{-0.3 \times 1.286}$$

$\approx$ **2.089 mg/l**

(*b*) ***DO deficit at a point 40 km downstream***

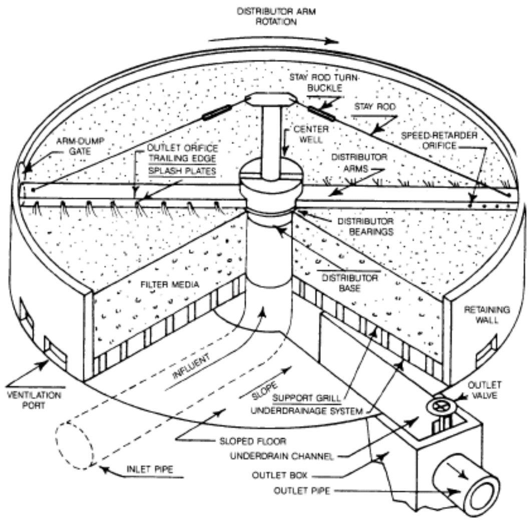
$$t = \frac{40 \times 1000}{0.18 \times 60 \times 60 \times 24} = 2.572 \text{ days.}$$

$$D_t = \frac{0.13 \times 8.71}{0.3 - 0.13}[10^{-0.13 \times 2.572} - 10^{-0.3 \times 2.572}] + 0.72 \times 10^{-0.3 \times 2.572}$$

$=$ **2.079 mg/l**

the rate of 1200

2.



Trickling filter is an ***attached growth process*** i.e. process in which microorganisms responsible for treatment are attached to an inert packing material. Packing material used in attached growth processes include rock, gravel, slag, sand, redwood, and a wide range of plastic and other synthetic materials.

A trickling filter consists of a bed of highly permeable media on whose surface a mixed population of microorganisms is developed as a *slime layer*. An attached growth process is happening in a trickling filter. Passage of wastewater through the filter causes the development of a gelatinous coating of bacteria, protozoa and other organisms on the media. With time, the thickness of the slime layer increases preventing oxygen from penetrating the full depth of then slime layer. In the absence of oxygen, anaerobic decomposition becomes active near the surface of the media.

Step by Step Process Description of Trickling Filter

- The wastewater in trickling filter is distributed over the top area of a vessel containing non-submerged packing material.
- Air circulation in the void space, by either natural draft or blowers, provides oxygen for the microorganisms growing as an attached biofilm.
- During operation, the organic material present in the wastewater is metabolised by the biomass attached to the medium. The biological slime grows in thickness as the organic matter abstracted from the flowing wastewater is synthesized into new cellular material.
- The thickness of the aerobic layer is limited by the depth of penetration of oxygen into the microbial layer.
- The micro-organisms near the medium face enter the endogenous phase as the substrate is metabolised before it can reach the micro-organisms near the medium face as a result of increased thickness of the slime layer and loose their ability to cling to the media surface. The liquid then

washes the slime off the medium and a new slime layer starts to grow. This phenomenon of losing the slime layer is called ***sloughing***.

- The sloughed off film and treated wastewater are collected by an under drainage which also allows circulation of air through filter. The collected liquid is passed to a settling tank used for solid- liquid separation.

3. **Sludge Digestion Process**

Sludge digestion involves the treatment of highly concentrated organic wastes in the absence of oxygen by anaerobic bacteria. The stabilization of sludge by decomposing the organic matter under controlled anaerobic conditions is called as ‗sludge digestion'. During this process of sludge digestion, sludge gets broken into three forms- 1) digested sludge 2) supernatant liquid 3) gases of decomposition. The digested sludge is also called as humus and it is black in colour and has less moisture and thus less volume. It will be free from pathogenic bacteria but may contain cysts and eggs of protozoa and helminths.

The supernatant liquor will have liquefied and finely divided solid matter with a high rate of BOD. Many odourous gases like methane, carbon dioxide, hydrogen sulphide are emitted from the process of sludge digestion.

The anaerobic treatment of organic wastes resulting in the production of carbon dioxide and methane, involves three distinct stages. In the first stage, referred to as "acid fermentation", complex waste components, including fats, proteins, and polysaccharides are first hydrolyzed by a heterogeneous group of facultative and anaerobic bacteria. This action of bacteria starts fermentation and the end products of this process will be acid carbonates and volatile organic acids and gases like methane, carbon dioxide and hydrogen sulphide. The pH value falls down less than 6. The second stage or the Acid Regression Stage is an intermediate stage where the volatile organic acids and the nitrogenous compounds of the first stage are attacked by the bacteria to form acid carbonates and ammonia compounds. The decomposed sludge emits offensive odour and its pH value rises to 6.8. The main feature of this stage is that the decomposed sludge and the entrapped gases of decomposition becomes foamy and rises to the surface of the digester forming scum. This stage continues for about 3 months or so and the amount of BOD will be very high.

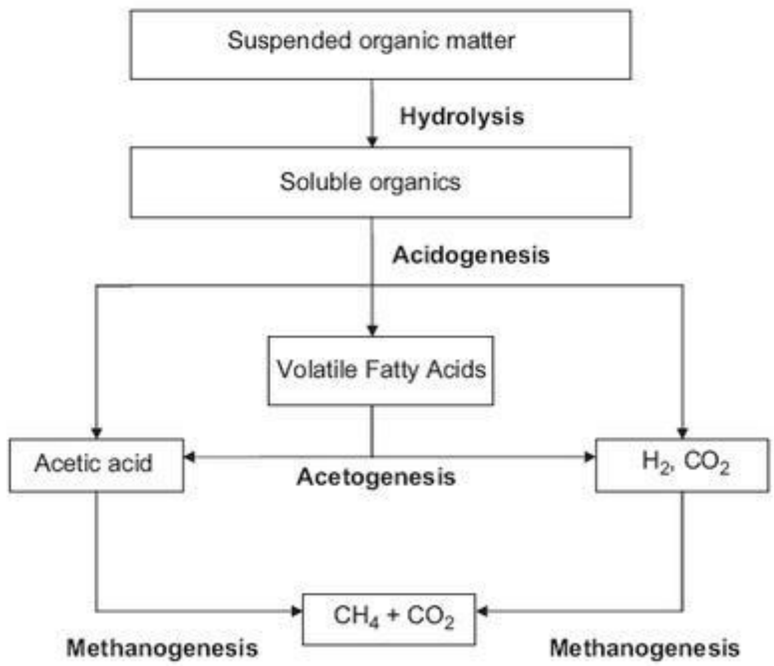
However in the third stage, referred to as "Alkaline fermentation", proteins and organic acids are decomposed by anaerobic bacteria into simple substances like ammonia, organic acids and gases.

The digested sludge, which is alkaline in nature (with a pH of 7.5), is formed in this stage and it gets separated out from the liquid. Large quantity of methane gas which has high calorific value is emitted from this stage. The sludge is also called as ripened sludge. BOD comes sown and this process takes almost one month to get over.

Stages of anaerobic sludge digestion (Extra reading)

In anaerobic digestion soft wet types of biomass are converted into biogas and digested state. It is a complicated process, requiring many types of bacteria to cooperate in series. The products of one type of bacteria are used as feedstock by the bacteria performing the next step in the chain.

To envisage the process, the series of conversions is divided into four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. The stages of anaerobic digestion process is depicted in figure.



Hydrolysis
The hydrolysis process transforms suspended organic matter into soluble organics. During the hydrolysis step, polymeric compounds are broken down by extra cellular enzymes into monomeric or dimeric compounds. The optimal pH for the hydrolysis step is 6, and the hydrolysis step usually is the rate limiting factor in anaerobic digestion.
A larger surface area enables enzymes to work faster because more enzymes are able to attack ‘ the organic material at the same time. Therefore a method to increase the rate of the hydrolysis is to increase the surface area of the substrate by previous grinding, boiling etc. Research is directed to apply this in practice. Also (bio)chemical pre-treatment of the organic material is being investigated, leading to more accessible polymers and hence to a higher rate and a higher degree of hydrolysis .
Also a two stage digester is used in practice, enabling the hydrolysis step to proceed under optimal conditions

Acidogenesis
In the acidogenesis process the soluble organics that were produced by the hydrolysis are transformed into volatile fatty acids, mostly C2-C4 acids. In essence, glucose (sugar) is transformed into acids. While hydrolysis is the slowest process, acidogenesis is the quickest process.
The production of volatile fatty acids lowers the pH in the digester. When the pH drops below 4, the production of acids stops. It is therefore necessary that the following steps, the acetogenesis and methanogenesis take place at a sufficient rate. Otherwise the whole process stops, if the digester has turned acidic.

Acetogenesis
In the acetogenesis process, the volatile fatty acids, (mostly) propionic acid, butyric acid and also ethanol are combined with water and are transformed into acetic acid, CO_2 and H_2.

Methanogenesis
In this step the acetic acid, CO_2 and H_2 are converted into methane. In a stable digestion process

around 70% of the methanogenesis converts acetic acid into CH_4 and CO_2, and this process is known as aceticlastic methanogenesis. This is the most efficient converstion from an energetic standpoint, as it produces the least amount of heat. The remaining 30% of the biogas is produced in the hydrogenotrophic methanogenesis, and this is the least effective energetic conversion. H_2 and CO_2 are converted into methane and water.

4. **NITROGEN REMOVAL**

Nitrogen in wastewater is found as Organic Nitrogen, Ammonia Nitrogen, Nitrate Nitrogen and Minor amounts of nitrite. All these forms are of nitrogen in wastewater effluents are potentially harmful. Nitrogen in the form of Ammonia is toxic to the fish. Most Nitrogen, when oxidized to nitrate may be used by the plants as nutrients. Nitrate itself is the causative agent of methemoglobinemia. Excess quantities in any form contributes to eutrophication of surface.

Nitrogen enters the aquatic environment from both natural and man-made sources. The large single source of Nitrogen is urea, which is together with Ammonia, comprises approximately 85% of the nitrogen excreta by man. Nitrogen can be removed from the waste water by progressive biological oxidation of the oxidation of Nitrogen compounds to nitrites and nitrates followed by conversion into Nitrogen gas. Thus, Nitrogen removal is in two distinct steps:

(i) Nitrification

(ii) Denitrification

In **Nitrification** ammonia is oxidized to nitrites and then to nitrates by aerobic nitrifying autotrophic bacteria.

In **Denitrification** nitrates are reduced to nitrogen gas by either autotrophic or heterotrophic bacteria. As a first step, bacterial decomposition releases ammonia by deamination of nitrogenous organic compounds. Continued aerobic oxidation results in nitrification. As a further step, biochemical Denitrification occurs with heterotrophic metabolism in an anaerobic environment.

Bacterial Decomposition

$$N\ (organic) \xrightarrow[\text{Deamination}]{\text{Bacterial Decomposition}} NH_3$$

$$NH_3 + O_2 \xrightarrow[\text{Nitrification}]{\text{Nitrifying Bacteria}} NO_3^-$$

$$NO_3^- \xrightarrow{\text{Bacterial denitrification}} N_2 \uparrow$$

Biological Nitrification:

Nitrification is the process in which Nitrosomonas bacteria oxidize ammonia to nitrite and Nitrobacter bacteria oxidize nitrite to nitrate. In is the process in which ammonia is first converted into nitrate form, thereby eliminating problem of toxicity to fish and reducing the nitrogen oxygen demand. The oxidation of ammonia to nitrate is a two-step process.

First step, ammonia is oxidized to nitrite by Nitrosonomas a genus of strict aerobic autotrophic bacteria.

$$NH_4 + 1.5\ O_2 \xrightarrow{\text{Nitrosonomas}} NO_2^- + H^+ + H_2O + Energy$$

Second step, the conversion of nitrite to nitrate, is accomplished by Nitrobacter, which is a genus of autotrophic bacteria.

The biological processes used for nitrification are identified as aerobic suspended growth and aerobic attached growth. This process results in the overall conversion of ammonia to nitrate. These microorganisms are autotrophic, which means they derive their carbon source from inorganic carbon, such as carbon dioxide and bicarbonate. Most other types of organisms in activated sludge are heterotrophic, which means they derive their carbon source from the organic matter in the wastewater. Environmental conditions of pH, alkalinity, temperature, dissolved oxygen concentration and organic loading affect the nitrification process in activated sludge plants.

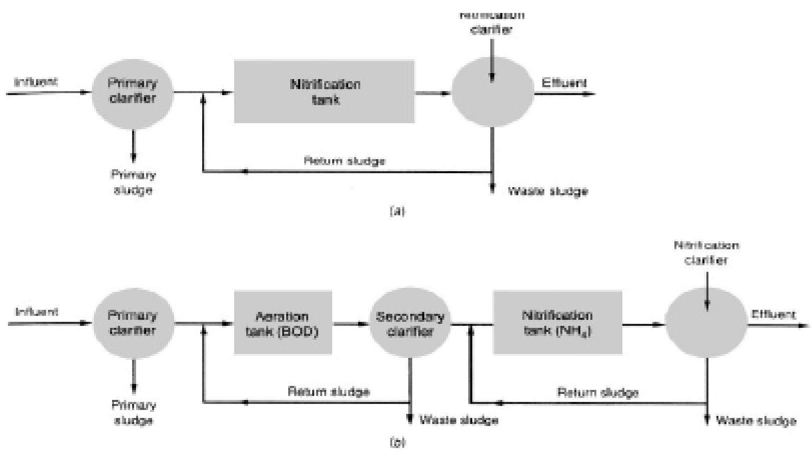
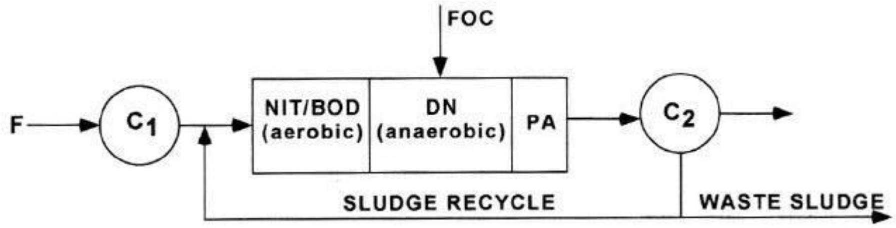


Fig. 5.1 (a) Single stage (b) Separate stage Nitrification Process

Denitrification is the process in which microorganisms reduce nitrate to nitrite and nitrite to nitrogen gas. In the denitrification process, a balanced amount of substrate is supplied to reduce the nitrate in the process of stabilization of the supplied substrate under anaerobic conditions.
Heterotrophic bacteria normally present in activated sludge perform this conversion when there is no molecular oxygen or dissolved oxygen, and there is sufficient organic matter. The bacteria derive their oxygen from the oxygen contained in the nitrate. Methanol (CH_3OH) has been used as a carbon source in denitrification. The nitrogen gas produced is in the form of nitric oxide (NO), nitrous oxide (N_2O) or nitrogen gas (N_2).

$$NO_3^- + \frac{5}{6} CH_3OH \rightarrow \frac{1}{2} N2 + \frac{5}{6} CO_2 + \frac{7}{6} H_2O + OH^-$$

The net removal of nitrogen is accomplished by stripping the nitrogen gas formed during denitrification out of the wastewater in a subsequent aeration process.



In post-denitrification systems, as seen in the middle diagram in the previous figure, BOD and nitrification occur first in an aerobic environment, followed by denitrification in an anoxic environment.

♦ Aerobic and anoxic conditions are controlled by the placement of aeration devices. For example, in a plug flow reactor, diffused aerators would be placed along the aerobic zone and no aerators would be placed in the anoxic zone.

♦ Post-denitrification systems have a post-aeration zone following the anoxic zone to strip the Nitrogen gas from the wastewater.

♦ Since most of the carbon source is consumed in the BOD/nitrification stage, a supplemental carbon source, typically methanol is added to the denitrification zone to support denitrifying bacteria. Denitrifying bacteria require a methanol-to-nitrogen ratio of about 3:1.

5. ELECTRO COAGULATION

♦ Electrocoagulation is a process of destabilising suspended, emulsified or dissolved contaminants in an aqueous medium by introducing electrical current into the medium. The electrical current provides the electromotive force causing the chemical reactions.

♦ Although the **electrocoagulation** mechanism resembles the **chemical coagulation** – the cationic species being responsible for the neutralisation of surface charges – in many ways it is very different.

♦ Electrocoagulation, the passing of the electrical current through water, has proven very effective in the removal of contaminants from water. Electrocoagulation systems have been in existence for many years using a variety of anode and cathode geometries, such as plates, balls, fluidised bed spheres, wire mesh, rods, and tubes.

Objectives:

- Typically to shift induced **pH** towards neutral.
- Removing heavy metals.
- Removing suspended and colloidal solids.
- Destabilizing oil and other emulsions.
- Removing fats, oils and grease.
- Removing complex organics and
- Destroying and removing bacteria, viruses and cysts.

Advantages:

- Treats multiple contaminants.
- Sludge minimization.
- Capital cost significantly less than conservative technologies.

- Operating cost significantly less than conservative technologies.
- Low power requirements;
- Generally, no chemical additions.
- Low maintenance.
- Minimal operator attention and
- Consistent and reliable results.

Construction:

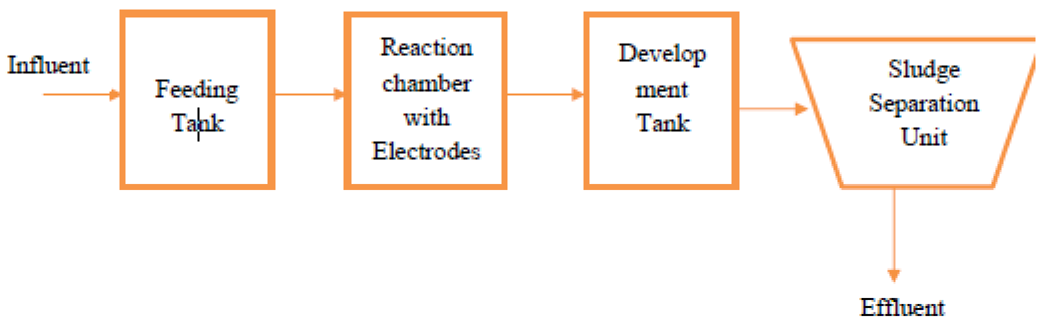


Fig. 5.8 Electro Coagulation Process

SOAK PITS

A soak pit is a circular covered pit, through which the effluent is allowed to be soaked or absorbed into the surrounding soil. The soak pit may either be filled with stone aggregate or may be kept empty. When the soak pit is empty, the pit is lined with brick, stone or concrete blocks with dry open joints.

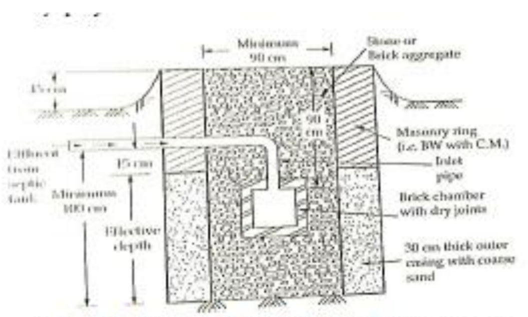


Fig. 5.12 Unlined soak pit filled with stone or brick aggregates

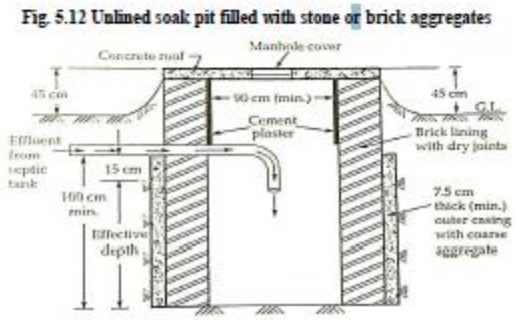


Fig. 5.13 Lined soak pit

♦ The soak pit should be between 1.5 and 4 m deep, but as a rule of thumb, never less than 2 m above the groundwater table.
♦ It should be located at a safe distance from a drinking water source (ideally more than 30 m).
♦ The soak pit should be kept away from high-traffic areas so that the soil above and around it is not compacted. It can be left empty and lined with a porous material to provide support and prevent collapse, or left unlined and filled with coarse rocks and gravel.
♦ The rocks and gravel will prevent the walls from collapsing, but will still provide adequate space for the wastewater. In both cases, a layer of sand and fine gravel should be spread across the bottom to help disperse the flow.
♦ To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained.

Advantages:

- Can be built and repaired with locally available materials.
- Technique simple to apply for all users.
- Small land area required.
- Low capital and operating costs.

Disadvantages:

- Primary treatment is required to prevent clogging.
- May negatively affect soil and groundwater properties.

ECO – TOILET

The term “eco-toilet” broadly refers to any toilets that by design minimize the contamination of clean water and also may have other environmental benefits. Eco-toilets range from toilets that merely package human waste for collection and disposal (thereby avoiding the mixing of wastes with clean water and minimizing the volume for easier disposal) to toilets that create nutrient-rich compost from human waste. **Composting toilets** use little or no water to send “waste” to chambers where it decomposes naturally in the presence of air, turning it into carbon-dioxide, water, and compost. A variant of the simple composting toilet incorporates
urine diversion (separation of urine from the solid faecal matter) and collects the urine in a separate container. This may allow for nutrient recovery from the urine.

Advantages:

1. Composting toilets are waterless systems. They help in environmental conservation by saving water that is normally used in copious amounts in conventional flush toilets. The waterless toilet saves more than 6,600 gallons of water annually for each person that visits the bathroom. 2. The composting toilet allows for on-site treatment of wastes making the process resourceful and cost-effective
3. The humus is far much safer to use and can be applied in non-edible gardens.
4. The use of composting toilets eliminates the potential threat of harmful by-products flowing into rivers and oceans. This helps in reducing environmental degradation.
5. The toilet is cheap to maintain as it uses basic materials. It is possible to add garden trimmings and vegetable peelings with toilet waste to enhance the decomposition process in the compost.
6. Composting toilets are hygienic. Batch system composting toilets enhance natural bacteria that allow the compost to kill toxins in human waste.