Unit II: Waste water treatment

The traditional aim of wastewater treatment is to enable wastewater to be disposed safely, without being a danger to public health and without polluting watercourses or causing other nuisance. Increasingly another important aim of wastewater treatment is to recover energy, nutrients, water, and other valuable resources from wastewater.

Types of sewage: There are three types of wastewater, or sewage:

- Domestic Sewage- carries used water from houses and apartments; it is also called sanitary sewage.
- Industrial Sewage- is used water from industrial processes,
- Storm Sewage- or storm water, is runoff from precipitation that is collected in a system of pipes or open channels.

The Composition of Wastewater:

Wastewater, also called sewage, is mostly water by mass (99.9%) (Figure 1). The contaminants in wastewater include suspended solids, biodegradable dissolved organic compounds, inorganic solids, nutrients, metals, and pathogenic microorganisms.

The suspended solids in wastewater are primarily organic particles, composed of : Body wastes, Food waste, Toilet paper.

Inorganic solids in wastewater include surface sediments and soil as well as salts and metals. The removal of suspended solids is essential prior to discharge in order to avoid settlement in the receiving watercourse. The degree to which suspended solids must be removed from wastewater depends on the type of receiving water into which the effluent is discharged.

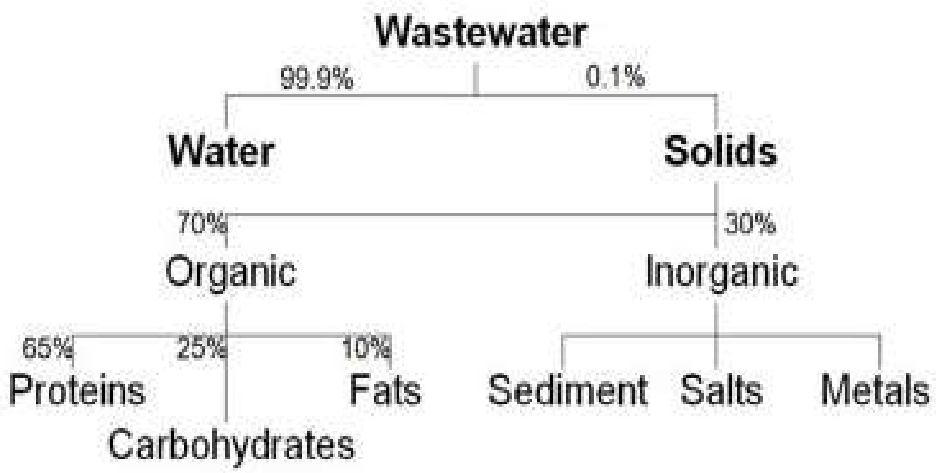


Figure 1 The typical approximate composition of domestic wastewater.

The biodegradable organics in wastewater are composed mainly of: Proteins (amino acids), Carbohydrates (sugars, starch, cellulose), Lipids (fats, oil, grease) These all contain carbon and can be converted to carbon dioxide biologically. Proteins also contain nitrogen.

CHARACTERISTICS OF SEWAGE

Physical Characteristics of Sewage:

1.Temperature

In general, under Indian condition the temperature of the raw sewage was observed to be between 15 to 35^{0}C at various places in different seasons. Temperature of wastewater is commonly higher than that of water supply. Depending on the geographic location the mean annual temperature varies in the range of 10 to 21^{0}C with an average of 16^{0}C.

Importance of temperature:
Temperature affects chemical reactions during the wastewater treatment process. It affects aquatic life also. Oxygen solubility is less in warm water than cold water. Optimum temperature for bacterial activity is in the range of 25°C to 35^{0}C. Aerobic digestion and nitrification stop when the temperature rises to 50^{0}C. When the temperature drops to about 15°C, methane producing bacteria become inactive. Nitrifying bacteria stop activity at about 5°C.

2. Colour and Odour

Fresh domestic sewage has a slightly soapy and cloudy appearance depending upon its concentration. As time passes the sewage becomes stale, darkening in colour with a pronounced smell due to microbial activity.
Odor is produced by gas production due to the decomposition of organic matter or by substances added to the wastewater. Detection of odor: Odor is measured by special instruments such as the Portable H_2S meter which is used for measuring the concentration of hydrogen sulfide.

Compound	Odor quality
Amines	Fishy
Ammonia	Ammonical
Diamines	Rotten eggs
Mercaptans	Decayed cabbage
Organic sulfides	Rotten cabbage
Skatole	Fecal matter

Color of waste water:
Fresh waste water - light brownish gray.
With time - dark gray
More time - black (septic)

3. Solids

Though sewage contains only about 0.1 percent solids the sewage solids may be classified into dissolved solids, suspended solids and volatile suspended solids.
Solids are classified into three main types:
1.Total Solids (TS): All the matter that remains as residue upon evaporation at 103oC to 105oC.
2. Settleable solids: Settleable solids are measured as ml/L, which is an approximate measure of the sludge that can be removed by primary sedimentation.

3. Suspended solids (SS) and Filterable solids (FS)

Chemical Characteristics of sewage:

Points of concern regarding the chemical characteristics of wastewater are: Organic matter, Inorganic matter, Gases & pH.

Organic matter (CaHbOc).75% SS (Suspended Solids) are organic & 40% FS (Filterable solids) are organic. Organic matter is derived from animals & plants and man activities. Proteins (40-60%), Carbohydrates (25-50%), Fats, Oils, and Grease (10%).

1. Nitrogen and Phosphorus

The principal nitrogen compounds in domestic sewage are proteins, amines, amino acids, and urea. Ammonia nitrogen in sewage results from the bacterial decomposition of these organic constituents. Nitrogen being an essential component of biological protoplasm, its concentration is important for proper functioning of biological treatment systems and disposal on land. Phosphorus is contributing to domestic sewage from food residues containing phosphorus and their breakdown products. The concentration of PO_4 in raw sewage is generally observed in the range of 5 to 10 mg/L.

2. Chlorides

Concentration of chlorides in sewage is greater than the normal chloride content of water supply.

3. pH: Generally the pH of raw sewage is in the range 5.5 to 8.0. The acidity or alkalinity of wastewater affects both treatment and the environment. The pH of wastewater needs to remain between 6 and 9 to protect organisms. Acids and other substances that alter pH can inactivate treatment processes when they enter wastewater from industrial or commercial sources.

***4.Gases*:-**The following are the main gases of concern in wastewater treatment:N_2, O_2, CO_2, H_2S, NH_3, CH_4

Biological Characteristics:

Main groups of Microorganisms:-

The main microorganisms of concern in wastewater treatment are Bacteria, Fungi, Algae, Protozoa, Viruses, and pathogenic microorganisms groups.

Bacteria:-Types: Spheroid, rod curved rod, spiral, filamentous. Some important bacteria:

Pseudomonas:-reduce $NO_3$to N_2, So it is very important in biological nitrate removal in treatment works.

Sphaerotilus natuns: Causes sludge bulking in the aeration tanks.

Bdellovibrio: Destroys pathogens in biological treatment.

Acinetobacter: Stores large amounts of phosphate under aerobic conditions and release it under an – anaerobic condition so, they are useful in phosphate removal.

Nitrosomonas: transform NH_4into NO_2^-

Nitrobacter: transform NO2-to NO3-

Coliform bacteria:-The most common type is *Echerichia coli*, (indicator for the presence of pathogens).

Zoogloea:-helps through its slime production in the formation of flocs in the aeration tanks.

Fungi:

Fungi are important in decomposing organic matter to simple forms.

Ex: *Saprolegnia, Leptomitus*, etc.

Algae: Cause eutrophication phenomena. (negative effect), Useful in oxidation ponds. (positive effect), Cause taste and problems when decayed. (negative effect)

Ex: *Sphaerotilus, Crenothrix, Beggiotoa, Rhodospirillales*, etc.

Protozoa:
Feed on bacteria so they help in the purification of treated waste water. Some of them are pathogenic.
Ex: *Entamoeba histolytica, Giradia*, etc.

Viruses: Viruses are a major hazard to public health. Some viruses can live as long as 41 days in water and wastewater at 20^{o}C. They cause lots of dangerous diseases.
Ex: *Enterovirus, Adenovirus, Hepatitis A,* etc.

Pathogenic organisms: The main categories of pathogens are: Bacteria, Viruses, protozoa, helminthes (as mentioned above)

BOD, COD & ThOD

In sanitary engineering there are two standard tests based on the oxidation of organic material: 1) the Biochemical Oxygen Demand (BOD) and 2) the Chemical Oxygen Demand (COD) tests. In both tests, the organic material concentration is measured during the test. The essential differences between the COD and the BOD tests are in the oxidant utilized and the operational conditions imposed during the test such as biochemical oxidation and chemical oxidation. The other method for measuring organic material is the development of the Total Organic Carbon (TOC) test as an alternative to quantify the concentration of the organic material.

Biochemical Oxygen Demand (BOD):
The BOD of the sewage is the amount of oxygen required for the biochemical decomposition of biodegradable organic matter under aerobic conditions. The oxygen consumed in the process is related to the amount of decomposable organic matter. The general range of BOD observed for raw sewage is 100 to 400 mg/L. $BOD_5$is the oxygen equivalent of organic matter. It is determined by measuring the dissolved oxygen used by microorganisms during the biochemical oxidation of organic matter in 5 days at 20^{o}C.

BOD measurements are used to:
Determine the approximate quantity of oxygen required to react with organic matter, the sizing of the wastewater treatment works, to measure the efficiency of some treatment processes.
BOD is calculated as:
BOD (mg/l) = (D1 - D2) / P
where D1 = initial DO (mg/l), D2 = final DO (mg/l), and P = fraction of wastewater per total volume of dilution water and wastewater.

Untreated domestic sewage typically has BOD in the range of 100-400 mg/l and a typical treatment target is to achieve BOD less than 30 mg/l, e.g. 80-90% reduction.

Chemical Oxygen Demand (COD):
The COD gives the measure of the oxygen required for chemical oxidation. It does not differentiate between biological oxidisable and nonoxidisable material. It is the oxygen equivalent of organic matter. It is determined by measuring the dissolved oxygen used during the chemical oxidation of organic matter in 3 hours.
The chemical oxidants such as potassium dichromate ($K_2Cr_2O_7$) or potassium permanganate($KMnO_4$) are used to measure the oxidisability of the organic matter of water where the oxidants oxidise the constitute.

Then potassium iodide is added which reacts with the excess amount of oxygen liberating iodine. By using starch indicator, iodine is titrated with sodium thiosulfate and amount is estimated.

However, the ratio of the COD to BOD does not change significantly for particular waste and hence this test could be used conveniently for interpreting performance efficiencies of the treatment units. In general, the COD of raw sewage at various places is reported to be in the range 200 to 700 mg/L.

In COD test, the oxidation of organic matter is essentially complete within two hours, whereas, biochemical oxidation of organic matter takes several weeks. In case of wastewaters with a large range of organic compounds, an extra difficulty in using BOD as a quantitative parameter is that the rate of oxidation of organic compounds depends on the nature and size of its molecules. Small molecules are readily available for use by bacteria, but large molecules, colloidal and suspended matter can only be metabolized after preparatory steps of hydrolysis. It is therefore not possible to establish a general relationship between the experimental five-day BOD and the ultimate BOD of a sample, *i.e.*, the oxygen consumption after several weeks. For sewage (with k=0.23 d-1 at 20oC) the BOD5 is 0.68 times ultimate BOD, and ultimate BOD is 87% of the COD. Hence, the COD /BOD ratio for the sewage is around 1.7.

Theoretical oxygen (ThOD): If the chemical formula of the organic matter existing in the WW is known the ThOD may be computed as the amount of oxygen needed to oxidize the organic carbon to carbon dioxide and a other end products.

$$C_6H12O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

WASTE WATER TREATMENT

Treatment Step	Processes
Primary	Removal of insoluble particulate materials by settling, screening, addition of alum and other coagulation agents, and other physical procedures
Secondary	Biological removal of dissolved organic matter
	Trickling filters
	Activated sludge
	Lagoons
	Extended aeration systems
	Anaerobic digesters
Tertiary	Biological removal of inorganic nutrients
	Chemical removal of inorganic nutrients
	Virus removal/inactivation
	Trace chemical removal

Preliminary Treatment:

The aim of preliminary treatment processes is to remove large and/or heavy debris which would otherwise interfere with subsequent unit processes or damage pumps and other mechanical equipment in the treatment works. Typically preliminary treatment includes screening and grit removal steps.

Screening:

Screening is the first step of treatment in a wastewater treatment works. The objective of screens is to remove large floating debris, such as rags (~60%), paper (~25%), and plastics (~5%). The materials that are removed from the water by the screens are referred to as screenings.

Grit Removal: The second step of preliminary treatment immediately downstream of screening is normally grit removal. Grit includes heavy inorganic particles such as sand, gravel, and other heavy particulate matter (e.g. corn kernels, bone fragments, coffee grounds). For design purposes grit is normally considered as fine sand, with a diameter of 0.2 mm, specific gravity of 2.65 mm, and a settling velocity of 20 mm/s.

Grit removal is an important preliminary treatment process for several reasons: To protect mechanical equipment and pumps from abrasive wear, Prevent pipe clogging by deposition of grit, Reduce accumulation of grit in settling tanks and digesters.

Primary treatment:

Sedimentation:

Wastewater contains impurities which in flowing water will remain in suspension but in quiescent water will settle under the influence of gravity. The sedimentation process, also called ‘settling’ or ‘clarification’, exploits this phenomenon and is used for the separation of solids from water and the concentration of separated solids. Sedimentation is used in both the primary and secondary treatment stages of wastewater treatment.

Septic tank: A septic tank is a sewage settling tank designed to retain the solids of the sewage entering the tank long enough to permit adequate decomposition of the sludge. Thus the unit accomplishes two processes: sedimentation and biological degradation of sludge.

Sewage enters the septic tank

↓

Sedimentation from the upper portion permitting a liquid with fewer suspended solids

↓

Sedimented suspended solids are discharged from the tank and subject to degradation by anaerobic bacteria

↓

Effluent from the septic tank is distributed under the soil surface through the disposal field

The septic tank is a solid holding tank usually constructed of concrete, fiberglass, steel, or polyethylene, designed specifically to accept all wastewater from the home, and ranges in capacity from 750 to 1,500 gallons based upon the size of the residence. Most homes have one large tank with two compartments, each of which is equipped with a lid located approximately three feet beneath ground level, or which may be fitted with lid risers that extend above ground level to accommodate access to the tank compartments for inspection and cleaning. The compartments are separated by means of a dividing wall, which has an opening midway between the floor and roof of the tank.

The septic tank connects the plumbing from the home, through the inlet pipe, also called the inlet baffle, to the absorption area, through the outlet pipe, or outlet baffle.

The inlet and outlet baffles are designed in the form of a T to allow liquid entry and egress without disturbing the forming layers of bacteria, nor allowing thick particles to travel back into the plumbing, inevitably causing a clog. Wastewater enters the first chamber of the tank, known as the solid side, and begins to separate into one of three layers:

The Scum Layer consists of soaps, greases, toilet paper, and other organic solid materials that float to the surface to decompose and eventually join the liquid layer.

The Liquid Layer consists of fairly clear water, separating the scum layer and the sludge, which flows through the opening in the dividing wall and into the second compartment, also known as the liquid side, for further filtration.

Sludge consists of heavy, inorganic, solid materials that sink to the bottom of the tank, and continue to build-up until cleaning takes place.

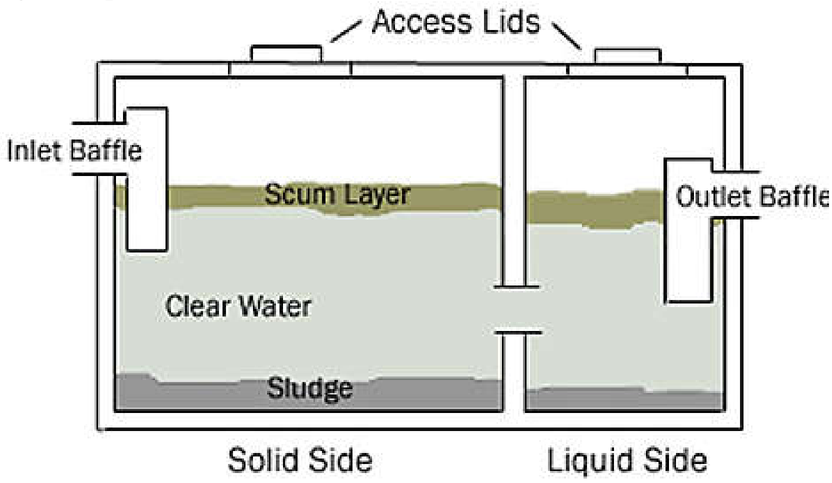


Fig.2 Septic Tank

Advantage: Septic tanks are most satisfactory method for disposing of sewage from small installations where public sewers are not available

Disadvantage: Inadequate for the removal of pathogens and drainage from the tank can contaminate the drinking water supply.

Imhoff tank:

Named for german engineer Karl Imhoff, is a chamber suitable for the reception and processing of sewage. It may be used for the clarification of sewage by simple settling and sedimentation along with anaerobic digestion of the extracted sludge.

It consists of an upper chamber in which sedimentation takes place from which collected solids slide down inclined bottom slopes to an entrance into a lower chamber in which the sludge is collected and digested. The lower chamber requires separate biogas vents and pipes for the removal of digested sludge.

The Imhoff tank was developed to correct the two main defects of the septic tank.

It prevents the solids once removed from the sewage from again being mixed with it, but still provides for the decomposition of these solids in the same unit

It provides an effluent amenable to further treatment.

Contact between the waste stream and the anaerobic digesting sludge is practically eliminated and the holding period in primary settling compartment at the tank is reduced. The Imhoff tank may be either circular or rectangular and is divided into three compartments:

1.the upper section or sedimentation compartment

2.the lower section known as the digestion compartment and

3.the gas vent and scum section

It is desirable to be able to reverse the direction of flow to prevent excessive deposition of solids at one end of the sedimentation compartment. Periodically reversing the flow will result in an even accumulation of sludge across the bottom of the tank. In operation, all of the wastewater flows through the upper compartment. Solids settle to the bottom of this sloped compartment, slide down and pass through an opening or slot to the digestion compartment. One of the bottom slopes extends at least six inches beyond the slot. This forms a trap to prevent gas or digesting sludge particles in the lower section from entering the waste stream in the upper section. The gas and any rising sludge particles are diverted to the gas vent and scum section.

The Imhoff tank has no mechanical parts and is relatively easy and economical to operate. It provides sedimentation and sludge digestion in one unit and should produce a satisfactory primary effluent with a suspended solids removal of 40 to 60 percent and a BOD reduction of 15 to 35 percent.

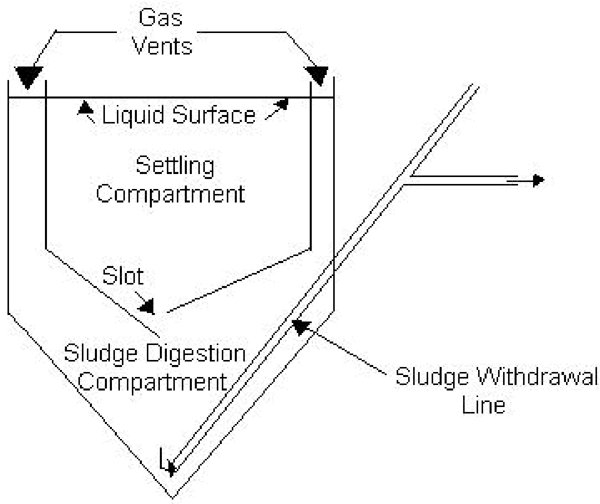


Fig. 3 Imhoff Tank

Secondary treatment:

In this biological degradation occurs in which the remaining suspended solids are decomposed by microorganisms and the number of pathogens is reduced. Effluent from primary treatment usually undergoes aerobic biological treatments such as- trickling filter, rotary biological contractors, fluidized bed reactors, stabilization ponds, activated sludge, aerated lagoons, etc.

Two type of sludge digestion:

Fixed film / attached growth' digestion- In this the cells are attached onto a surface as a biofilm and the water is passed over the surface.

Ex: trickling filter, rotary biological contractors, fluidized bed reactors

Dispersed growth digestion- In this the bacterial cells are suspended in the water column in a tank.

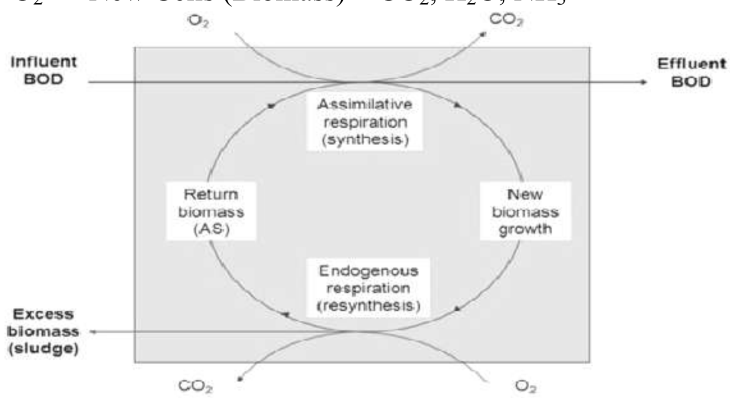
Ex:stabilization ponds, activated sludge, aerated lagoons

The aim of biological treatment is to transfer dissolved organic contaminants (e.g. BOD) from a soluble form into suspended matter in the form of cell biomass, which can then be subsequently removed by particle-separation processes (e.g. sedimentation).

The most effective biological processes for removing dissolved organics in this way are aerobic processes, since they are fastest and their products are relatively inoffensive (H2O, CO2). Typically oxygen must be added to the wastewater to support the aerobic process, either through bubbling air into the water or through mixing.

Conceptually, the aerobic process can be simplified as:

Organic Matter + Bacteria + O_2 → New Cells (Biomass) + CO_2, H_2O, NH_3



1) Trickling Filters

The key components of a trickling filter (Figure5) are:

1. A dosing system for applying the wastewater
2. A bed of randomly packed solid media
3. An under drainage system for collection of the treated effluent
4. A ventilation system for supplying oxygen to the filter
5. A system for separating the detached biofilm (also called humus) from the treated effluent.

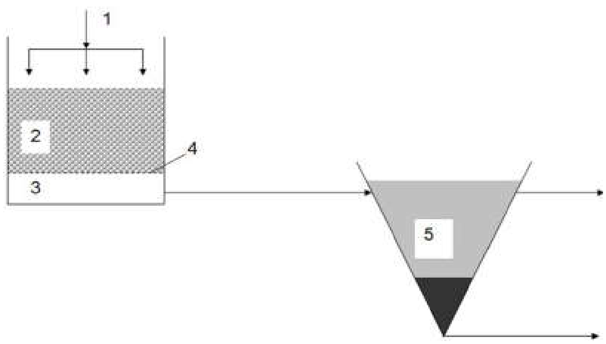


Figure 5. The key components of a trickling filter process.

Wastewater is spread on the media surface and trickles down through the media on which the biofilm is attached. The biological activity of the biofilm is the primary mechanism of removal of dissolved organic matter, more so than filtration / attachment onto the media surface. BOD stabilisation occurs at the film / wastewater interface with a fairly short contact time (20-30 seconds). The process works due to the large surface area of the biofilm on the media surfaces. Because the organisms remain in place attached to the media surfaces, very long sludge ages and high cell masses can be achieved. Conditions in trickling filters are mainly aerobic and the microbial community includes a mixture of bacteria, protozoa, and fungi. The biofilm (zoogleal film) organisms are attached to the surface and protected by a coating of extracellular polysaccharides (EPS), leading to a very robust, hardy film that can tolerate changing conditions quite well. The biofilm layer is microscopic in thickness (i.e. << 1mm).

Biofilm growth is outwards from the media surface, eventually leading to 'sloughing', due to endogenous decay and anaerobic conditions at the biofilm/media interface. Attachment weakens and the film shears off; the biofilm quickly re- establishes, however. The sloughed biofilm is referred to as 'humus'. The humus is removed from the treated effluent by a clarifier downstream. Humus normally settles well and is often re-circulated to the primary clarifier to serve as a settling aid.

The regular sloughing of the biofilm results in an effluent that is low in BOD but high in SS, therefore the design and operation of the secondary clarifier is critical. Higher loading rates can be used for the secondary clarifier than in activated sludge treatment due to the good settling characteristics of the humus.

Modern trickling filters use synthetic media which are specially designed to have large surface area and porosity and typically made of plastic. Traditional media include crushed stone, typically with 25-100 mm diameter and a maximum 2 m bed depth. Other media include rock, slag, and redwood.

The filter is not submerged, so as to encourage aerobic conditions. Oxygen in the wastewater and air supplied through ventilation allow aerobic conditions to be maintained. The rate of wastewater application must be controlled to avoid flooding the filter bed. The concentration of influent substrate must also be well understood in order to avoid too much biological growth and hence plugging of the filter. It is also important to avoid freezing of the filter in winter in cold climates.

A conventional trickling filter plant can achieve a 20:30 effluent (i.e. < 20 mg/l of BOD, < 30 mg/l of SS) at the organic loading rates between 0.06-0.12 kg BOD per m3 per day or hydraulic loading rates of 0.25-1.2 m^3 per m^2 per day.

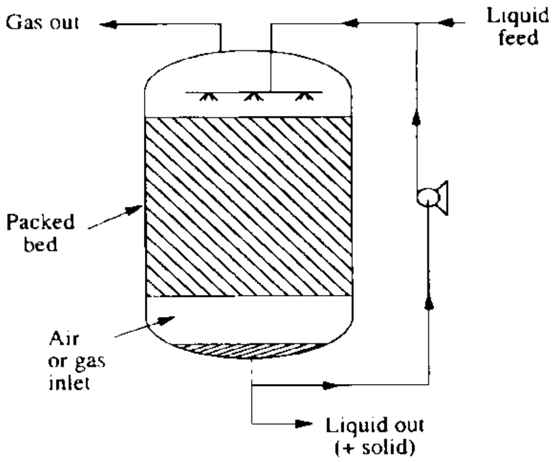


Figure 6. Trickling filter process

The advantages of trickling filters are:

- Generally able to meet a 20:30 effluent standard, with nitrification at lower rates
- No / low power requirements
- Relatively simple operation
- Quiet and does not foam
- Quicker recovery to changes in influent BOD and flow (compared to activated sludge)
- Easier secondary clarifier design due to good settling of humus.

The disadvantages of trickling filters include:

- Higher space requirements than activated sludge
- Possible fly and odor problems
- Possibly clogging problems.

2) Rotating Biological Contactors:

Rotating biological contactors (RBCs) are another type of attached growth process, consisting of a series of closely packed plastic discs of a shaft, rotating and partially submerged in wastewater. RBCs use the same principles as a trickling filter except now the media rotates and the wastewater is stationary. Rotation of the discs allows alternating contact of the biological film on the disc with the organic matter in the wastewater and then with the oxygen in the air, thereby maintaining aerobic conditions. During the passage in the air or gas space, the liquid drains from the plates or packing and oxygen can diffuse in the remaining thin film of liquid and ultimately reach the biomass itself, and simultaneously CO_2 can escape. The rotation of the discs also removes excess solids by shearing and maintains the sloughed material in suspension for removal in a downstream clarifier. RBCs are a more intensified process than trickling filters, with higher concentrations of organisms in the biofilm. RBCs can easily achieve a 20:30 effluent, with typically greater than 90% removal of BOD. It should also be remarked that a fully submerged operation is possible in the case of anaerobic operation.

The discs are made of wood, metal or plastic. They are typically up to 4 m in diameter and rotate on a shaft up to 7 m long at a rotational speed of 1-2 rotations per minute, with 40% of the discs immersed in wastewater. As with trickling filters, the design of RBCs is based largely on empirical relationships. The key design variables are the media design, the speed of the drive shaft, the trough volume below the discs, and the depth of immersion. A typical loading rate is 3-8 g of BOD per m2 per day, although high rate variations can treat 20+ g of BOD per m2 per day.

Primary sedimentation is critical to RBC operation, to avoid excessive amounts of larger solids settling between the discs and impeding their rotation. Secondary sedimentation is equally important to remove the high concentrations of sloughed biomass from the treated effluent. RBCs can also operate in nitrification / denitrification modes by tailoring the disc immersion ratio and rotational speed.

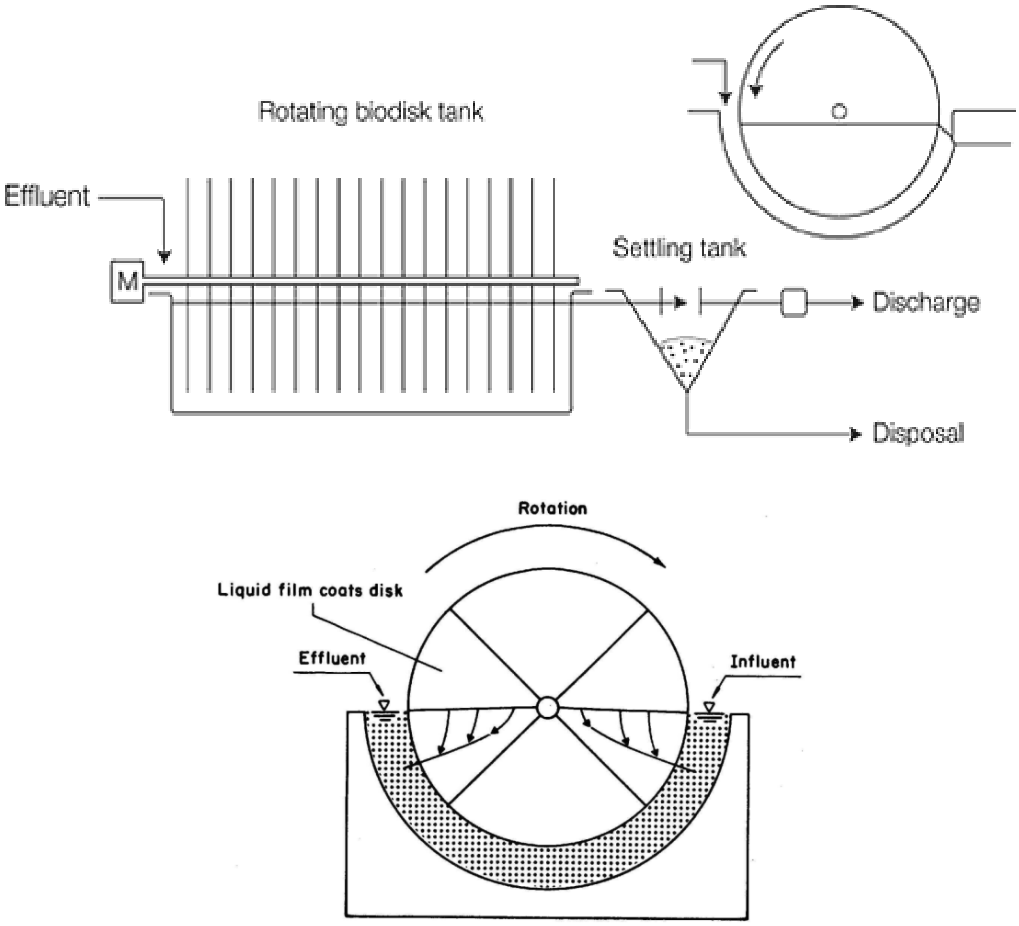


Figure 7. Rotating biological contactors

The advantages of RBCs include:

- Compact size (small land requirement compared to equivalent treatment by trickling filters)
- Ease of operation
- Low power consumption relative to activated sludge (no need for aeration)
- Usually no need to recycle the sludge.

The disadvantages of RBCs include:

- Must protect from weather (heat, cold, intense sunlight)
- High capital cost
- Potential for mechanical failures.

Stabilization Ponds or oxidation ponds:

A stabilization pond or "oxidation pond" as it is often called, is usually a shallow earthen basin of controlled shape, which is designed for treating wastewaters from small communities or industrial plants. The ponds are usually 2 to 4 feet deep, although much deeper ponds have been used quite successfully. Stabilization ponds have been applied singly as part of a treatment scheme or as the sole process, providing complete treatment.

The process involves two major steps in the decomposition of organic matter in wastewater. The carbonaceous matter is first oxidized by the aerobic microorganisms with the formation of carbon dioxide and the inorganic forms of nitrogen and phosphorous. These inorganic forms are then used by algae in their photosynthetic reactions. Photosynthesis is a natural process carried on by green plants in the presence of light. One of the end products of photosynthesis is oxygen which becomes available to the aerobic microorganisms. As a result of the reactions in the ponds, the organics in wastewater are partly oxidized and partly converted to algae cells. Algae has been harvested in some of the locations and used for animal feed as a protein source. Therefore, treatment of wastewater with the production of a useful by-product is possible in stabilization ponds.

Waste stabilization ponds are mainly shallow man-made basins comprising a single or several series of anaerobic, facultative or maturation ponds The primary treatment takes place in the anaerobic pond, which is mainly designed for removing suspended solids, and some of the soluble element of organic matter (BOD_5). During the secondary stage in the facultative pond most of the remaining BOD5 is removed through the coordinated activity of algae and heterotrophic bacteria. The main function of the tertiary treatment in the maturation pond is the removal of pathogens and nutrients (especially nitrogen).

The stabilization ponds are classified as:

1. Anaerobic ponds
2. Facultative ponds
3. Maturation ponds

1. **Anaerobic ponds**

These units are the smallest of the series. Commonly they are 2-5 m deep and receive high organic loads equivalent to 100 g BOD_5/m^3d. These high organic loads produce strict anaerobic conditions (no dissolved oxygen) throughout the pond. In general terms, anaerobic ponds function much like open septic tanks and work extremely well in warm climates. A properly designed anaerobic pond can achieve around 60% BOD_5 removal at 20°C. One-day hydraulic retention time is sufficient for wastewater with a BOD5 of up to 300 mg/l and temperatures higher than 20°C. Designers have always been preoccupied by the possible odour they might cause. However, odour problems can be minimized in well designed ponds, if the SO42- concentration in wastewater is less than 500 mg/l. The removal of organic matter in anaerobic ponds follows the same mechanisms that take place in any anaerobic reactor.

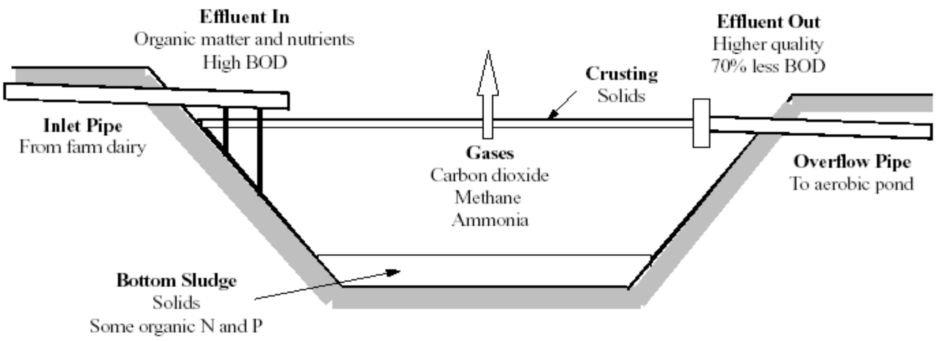


Fig 8. Anaerobic stabilization pond

2. **Facultative ponds**

These ponds are of two types: primary facultative ponds receive raw wastewater, and secondary facultative ponds receive the settled wastewater from the first stage (usually the effluent from anaerobic ponds). Facultative ponds are designed for BOD5 removal on the basis of a low organic surface load to permit the development of an active algal population. This way, algae generate the oxygen needed to remove soluble BOD5. Healthy algae populations give water a dark green colour but occasionally they can turn red or pink due to the presence of purple sulphide-oxidising photosynthetic activity. This ecological change occurs due to a slight overload. Thus, the change of colouring in facultative ponds is a qualitative indicator of an optimally performing removal process. The concentration of algae in an optimally performing facultative pond depends on organic load and temperature, but is usually in the range 500 to 2000 & 956 g chlorophyll per litre. The photosynthetic activity of the algae results in a diurnal variation in the concentration of dissolved oxygen and pH values. Variables such as wind velocity have an important effect on the behaviour of facultative ponds, as they generate the mixing of the pond liquid. A good degree of mixing ensures a uniform distribution of BOD5, dissolved oxygen, bacteria and algae, and hence better wastewater stabilization.

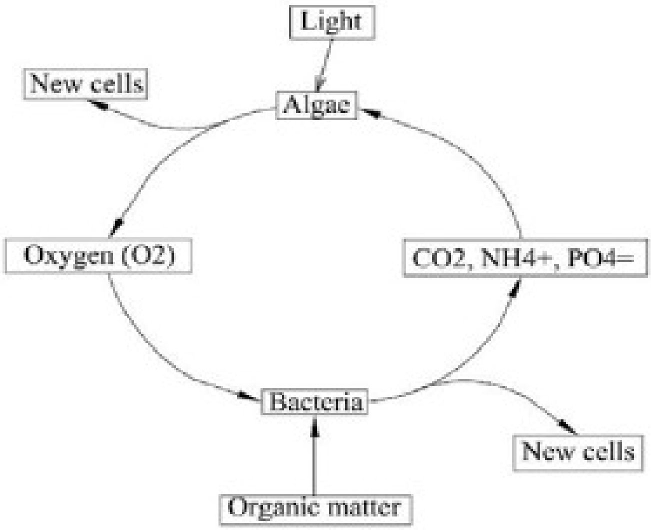


Figure 9: Schematic representation of facultative Ponds

3. **Maturation ponds**

These ponds receive the effluent from a facultative pond and its size and number depend on the required bacteriological quality of the final effluent. Maturation ponds are shallow (1.0-1.5 m) and show less vertical stratification, and their entire volume is well oxygenated throughout the day. Their algal population is much more diverse than that of facultative ponds. Thus, the algal diversity increases from pond to pond along the series. The main removal mechanisms especially of pathogens and faecal coliforms are ruled by algal activity in synergy with photo-oxidation.

On the other hand, maturation ponds only achieve a small removal of BOD5, but their contribution to nitrogen and phosphorus removal is more significant. A total nitrogen removal of 80% in all waste stabilization pond systems, which in this figure corresponds to 95% ammonia removal. It should be emphasised that most ammonia and nitrogen is removed in maturation ponds. However, the total phosphorus removal in WSP systems is low, usually less than 50%.

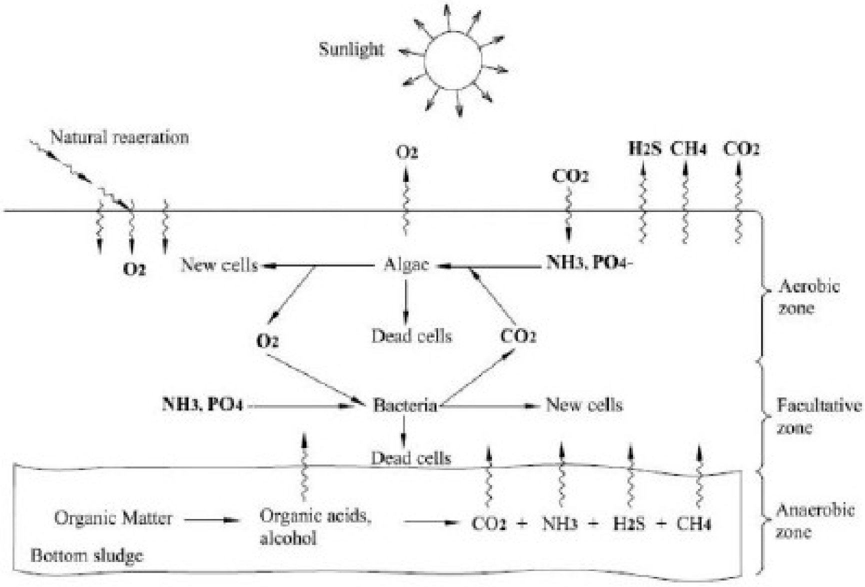
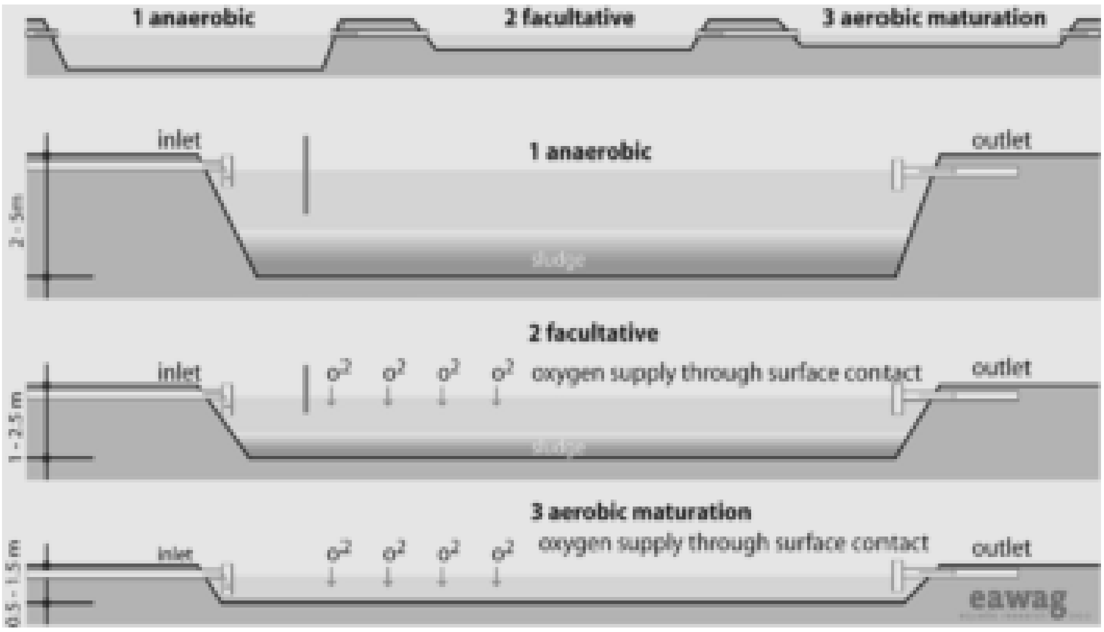


Fig.10 Mutual relationship between pond algae and bacteria



Advantages of stabilization ponds

-High reduction in pathogens.

- Can be built and repaired with locally available materials.
- Construction can provide short-term employment to local laborers.
- No electrical energy required.
- No real problems with flies or odours if designed correctly.

-Simplicity in design and construction

-Low production of biological sludge

-Low capital, operation and maintenance cost

-Robust and relatively reliable

-Less sensitive to shock loading

Disadvantages/limitations of stabilization ponds

- Requires expert design and supervision.
- Variable capital cost depending on the price of land.
- Requires large land area.
- Effluent/sludge require secondary treatment and/or appropriate discharge.
-Sludge accumulation will be higher in cold climates due to reduced microbial activity
-Mosquitoes and other insects can breed if vegetation is not controlled
-If not designed properly may cause odour problem
-Difficult to control or predict ammonia levels in effluent

Activated Sludge System

An aerobic activated sludge system involves the horizontal flow of materials with recycling of sludge—the active biomass that is formed when organic matter is oxidized and degraded by microorganisms. Activated sludge systems can be designed with variations in mixing. In addition, the ratio of organic matter added to the active microbial biomass can be varied. A low rate system (low nutrient input per unit of microbial biomass), with slower growing microorganisms, will produce an effluent with low residual levels of dissolved organic matter. A high-rate system (high nutrient input per unit of microbial biomass), with faster growing microorganisms, will remove more dissolved organic carbon per unit time but produce a poorer quality effluent.

The combination of waste water and biological mass is commonly known as mixed liquor. In all activated sludge plants, once the waste water has received sufficient treatment, excess mixed liquor is discharged into settling tanks and the treated supernatant is run off to undergo further treatment before discharge. Part of the settled material, the sludge, is returned to the head of the aeration system to re-seed the new waste water entering the tank. This fraction of the floc is called return activated sludge (RAS). Excess sludge is called surplus activated sludge (SAS) or waste activated sludge (WAS).

The activated sludge process involves

- Aerobic digestion
- Anaerobic digestion

Aerobic digestion is an extension of the activated sludge aeration process whereby waste primary and secondary sludges are continually aerated for long periods of time. In aerobic digestion the microorganisms extend into the endogenous respiration phase, which is a phase where materials previously stored by the cell are oxidized, with a reduction in the biologically degradable organic matter. This organic matter, from the sludge cells is oxidized to carbon dioxide, water and ammonia. The ammonia is further converted to nitrates as the digestion process proceeds.

Eventually, the oxygen uptake rate levels off and the sludge matter is reduced to inorganic matter and relatively stable volatile solids. The major advantage of aerobic digestion is that it produces a biologically stable end product suitable for subsequent treatment in a variety of processes. Volatile solids reductions similar to anaerobic digestion are possible.

Parameters: Some parameters affecting the aerobic digestion process are: (1) rate of sludge oxidation, (2) sludge temperature, (3) system oxygen requirements, (4) sludge loading rate, (5) sludge age, and (6) sludge solids characteristics.

Design: Aerobic digestion has been applied mostly to various forms of activated sludge treatment, usually "total oxidation" or contact stabilization plants. However, aerobic digestion is suitable for many types of municipal and industrial wastewater sludges, including trickling filter humus as well as waste activated sludges. Any design for an aerobic digestion system should include: an estimate of the quantity of sludge to be produced, the oxygen requirements, the unit detention time, the efficiency desired, and the solids loading rate.

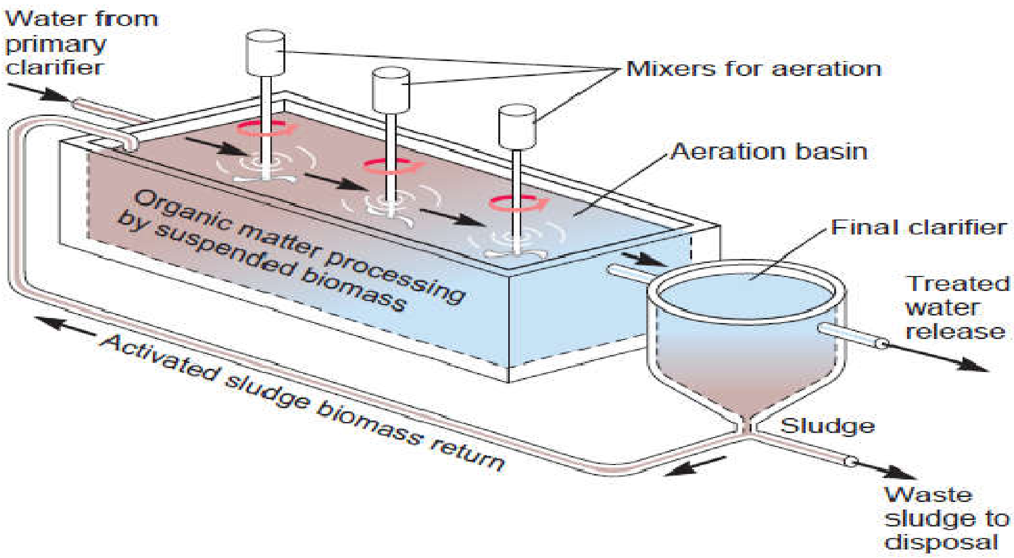


Fig. 11 Activated sludge process in aerobic sludge digester

Air Requirement: A dissolved oxygen concentration of 1 to 2 ppm should be maintained in the aerobic digestion tanks.

Tank Design: Aerobic digestion tanks are normally not covered or heated, therefore, they are much cheaper to construct than covered, insulated, and heated anaerobic digestion tanks. In fact, an aerobic digestion tank can be considered to be a large open aeration tank. Similar to conventional aeration tanks, the aerobic digesters may be designed for spiral roll or cross roll aeration using diffused air equipment. The system should have sufficient flexibility to allow sludge thickening by providing supernatant decanting facilities.

The advantages most often claimed for aerobic digestion are:

- A humus-like, biologically stable end product is produced.
- The stable end product has no odors, therefore, simple land disposal, such as lagoons, is feasible.
- Capital costs for an aerobic system are low, when compared with anaerobic digestion and other schemes.
- Aerobically digested sludge usually has good dewatering characteristics. When applied to sand drying beds, it drains well and re-dries quickly if rained upon.
- The volatile solids reduction can be equal to those achieved by anaerobic digestion.
- Supernatant liquors from aerobic digestion have a lower BOD than those from anaerobic digestion. Most tests indicated that BOD would be less than 100 ppm. This advantage is important because the efficiency of many treatment plants is reduced as a result of recycling high BOD supernatant liquors.

Disadvantages:

- The major disadvantage associated with aerobic digestion is high power costs.

- Some sludges do not dewater easily by vacuum filtration after being digested aerobically. Two other minor disadvantages are the lack of methane gas production and the variable solids reduction efficiency with varying temperature changes.

Anaerobic sludge digestion:

The purpose of the anaerobic process is to convert sludge to end products of liquid and gases while producing as little biomass as possible. The process is much more economical than aerobic digestion. Anaerobic digestion is accomplished in following four stages:

1. Hydrolysis: large polymers are broken down by enzymes.
2. Fermentation: Acidogenic fermentations are most important, acetate is the main end product. Volatile fatty acids are also produced along with carbon dioxide and hydrogen.
3. Acetogenesis: Breakdown of volatile acids to acetate and hydrogen.
4. Methanogenesis: Acetate, formaldehyde, hydrogen and carbon dioxide are converted to methane and water.

An anaerobic sludge digester is designed to encourage the growth of anaerobic bacteria, particularly the methane producing bacteria that decreases organic solids by reducing them to soluble substances and gases, mostly carbon dioxide and methane. The sludge that remains is relatively stable and inert. From 50% to 60% of the organics are metabolized with less than 10% converted to biomass.

The anaerobic process is made up of two basic types of bacteria. The acid formers and the methane formers. The acid formers are facultative and anaerobic bacteria and include organisms that solubilize organic solids through hydrolysis. Soluble products are then fermented to acids and alcohols of low molecular weight. The methane formers are strict anaerobics that convert acids and alcohol along with hydrogen and carbon dioxide to methane.

Stability of the anaerobic process is difficult to maintain because a balance favorable to several microbial populations is necessary. The methane producers are the most sensitive to conditions. They may be affected by change in the pH of the digesting sludge. Each species is limited to the use of a few compounds, mostly alcohols and organic acids. The rugged nature of the acid formers and the sensitive nature of the methane formers creates a bio system that is easily upset.

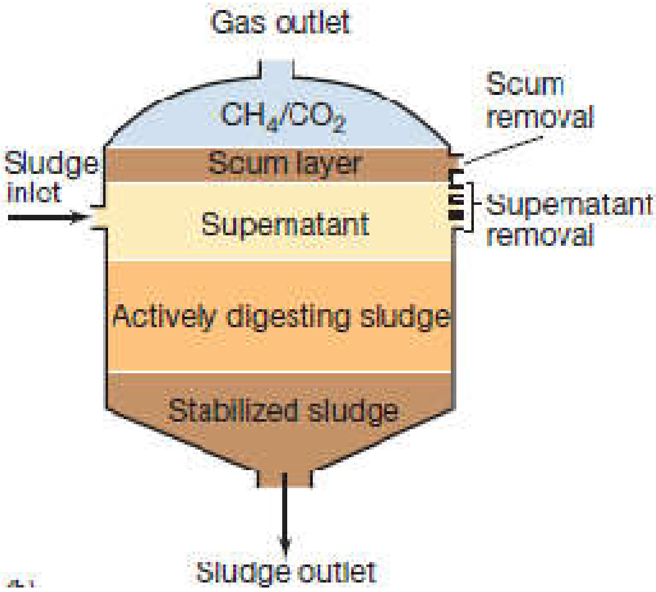


Fig. 12 Anaerobic Sludge digester

Tertiary wastewater treatment:

Tertiary wastewater treatment is any physicochemical or biological process employing bioreactors, precipitation, filtration, or chlorination procedures similar to those employed for drinking water purification; absorptive processes, such as the use of activated carbon; more efficient oxidation, as with ozone; foam separation of impurities and demineralisation using reverse osmosis or distillation . Operations installed for tertiary treatment can also involve more exotic and expensive equipment such as electrodialysis units or ion exchange columns. Tertiary treatment sharply reduces levels of inorganic nutrients, especially phosphate, nitrite, and nitrate, from the final effluent and cannot support extensive microbial growth. Tertiary treatment is the most complete method of treating sewage but has not been widely adopted due to the costs associated with such complete nutrient removal.