Version 1.0

WASTE WATER GUIDE
FOR ENGINEERS

A holistic approach by
Ahmedabad Municipal Corporation and DNP Foundation

DNP

Preface :

This Publication has a goal to give user's practice topics with exam questions that will be helpful in field work, simple methods of waste treatment with reducing cost and complexity of treatment without sacrificing the requirement of pollution control has been elaborated with unified approach.

This book is in part the result of field work as a Municipal Corporation expert.

The topics test the skill and knowledge required of an engineer and operator working in waste water treatment plant.

This book contains new developments and changes that have been occurred in the field of waste water engineering with respect to :

1. *Characteristics of the consequences found in the waste water.*
2. *Greater fundamental understanding of bio logical waste water treatment.*
3. *Application of advance treatment for removal of specific constitutes.*

The topic included in this book have been chosen to sample as many different aspect of wastewater treatment job responsibility as possible ,however because of the tremendous variety in equipment's, processes, conditions and duties all of the topics may not be useful in all of the application but, it will be prove pathway for achieving goal.

References :

Wastewater Engineering (Treatment and Reuse) Metcalf & Eddy

The STP Guide (Design Opertion and Maintenance) by Ananth S. Kodavasal, Ph.D. Published by of Karnatak State Pollution Control Board .

CONTENTS

CHAPTER-1

WASTEWATER MANAGEMENT

BACKGROUND :

- Urbanization has given rise to a number of environmental problems such as, water supply with desirable quality and quantity, wastewater generation and its collection, treatment and disposal.
- In urban areas, for domestic and industrial uses the source of water is generally reservoir, river, lake, and wells.
- Out of total water supplied, generally 60 to 80% contributes as a wastewater. In most of the cities, wastewater is let out partially treated or untreated and it either percolates into the ground and in turn contaminates the ground water or it is discharged into the natural drainage system causing pollution in downstream water bodies.
- In India, water pollution comes from the main sources such as domestic sewage, industrial effluents, leachates from landfills, and run-off from solid waste dumps and agriculture land.
- Domestic sewage (black water) and sullage (grey water) is the main source of water pollution in India
- The mixture of water and waste products is known as sewage.

SOURCES OF SEWAGE :

- The wastewater generated from recreational activities, public utilities, commercial complexes, and institutions is also discharged in to sewers.

DEFINITIONS :

- **Industrial wastewater:** It is the wastewater generated from the industrial and commercial areas. This wastewater contains objectionable organic and inorganic compounds that may not be amenable to conventional treatment processes.
- **Night Soil:** It is a term used to indicate the human and animal excreta.
- **Sanitary sewage:** Sewage originated from the residential buildings comes under this category. It is the wastewater generated from the lavatory basins, urinals and water closets of residential buildings, office building, theatre and other institutions. It is also referred as domestic wastewater.
- **Sewage:** It indicates the liquid waste originating from the domestic uses of water. It includes sullage, discharge from toilets, urinals, wastewater generated from commercial establishments, institutions, industrial establishments and also the groundwater and stormwater that may enter into the sewers.
- **Sewage Treatment Plant** is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water receiving systems or land.
- **Sewer:** It is an underground conduit or drain through which sewage is carried to a point of discharge or disposal.
- **Sewerage:** The term sewerage refers the infrastructure which includes device, equipment and appurtenances for the collection, transportation and pumping of sewage, but excluding works for the treatment of sewage.
- **Storm water:** It indicates the rain water of the locality.
- **Subsoil water:** Groundwater that enters into the sewers through leakages is called subsoil water.
- **Sullage:** This refers to the wastewater generated from bathrooms, kitchens, washing place and wash basins, etc. Composition of this waste does not involve higher concentration of organic matter and it is less polluted water as compared to sewage.
- **Wastewater:** The term wastewater includes both organic and inorganic constituents, in soluble or suspended form, and mineral content of liquid waste carried through liquid media

OBJECTIVES OF SEWAGE COLLECTION AND DISPOSAL :

- Efficient sewerage scheme can achieve the following :
- To provide a good sanitary environmental condition of city protecting public health.
- To dispose the human excreta to a safe place by a safe and protective means.
- To dispose of all liquid waste generated from community to a proper place to prevent a favourable condition for mosquito breeding, fly developing or bacteria growing.
- To treat the sewage, as per needs, so as not to endanger the body of water or groundwater or land to get polluted where it is finally disposed off. Thus, it protects the receiving environment from degradation or contamination.

THE ADVANTAGES OFFERED BY THE WATER CARRIAGE SYSTEM :

- The old system was posing the health hazards to sweepers and to the nearby residents, because of the possibilities of flies and insects transmitting disease germs from the accessible carts to the residents food eatables. This is avoided in water carriage system because of transport of night soil in close conduits.
- The human excreta is washed away as soon as it is produced in water carriage system, thus storing is not required as required in the old system of manual disposal. Thus, no bad smells are produced in closed conduit transport.
- In the old system, the wastewater generated from the kitchen and bathrooms was required to be carried through open road side drains for disposal.
- This is avoided in sewerage system as the open drains could generate bad odours when used for disposal of organic wastes.
- The water carriage system does not occupy floor area, as the sewers are laid underground.

HOWEVER, THIS WATER CARRIAGE SYSTEM ALSO HAS CERTAIN DRAWBACKS SUCH AS :

- A large network of pipes is required for collection of the sewage; hence, the capital cost for water carriage system is very high.
- In addition, the operation and maintenance of sewerage system is very expensive.
- Large wastewater volume is required to be treated before disposal.
- Assured water supply is essential for efficient operation of the water carriage system.

WASTEWATER TREATMENT :

- Waste water treatment will facilitate protection of environment and environmental conservation, because the wastewater collected from cities and towns must ultimately be returned to receiving water body or to the land or reused to full fill certain needs.
- The sewage treatment plants constructed near the end of nineteenth century were designed to remove suspended matter alone by the principal of simple gravity settling.
- In the beginning of twentieth century several treatment systems, called secondary treatment, were developed with the objective of organic matter removal.
- For this secondary treatment, biological methods are generally used. The aerobic biological treatment processes were popularly used as a secondary treatment, and these processes are still at the first choice.

- In the second half of twentieth century, it became clear that the discharge of effluents from even the most efficient secondary treatment plant could lead to the deterioration of the quality of receiving water body due to discharge of ammonia in the effluent.
- Even when nitrification is carried out at the treatment plant itself, the discharge of effluent can still be detrimental to the water quality due to introduction of nitrogen in the form of nitrate and phosphorus as phosphate. Explosive development of biomass may occur when nitrogen and phosphorus are abundantly available.
- This biomass may produce photosynthetic oxygen in the water during daytime, after sunset it will consume oxygen, so that the dissolved oxygen concentration will decrease and may reach to the levels that are too low to sustain the life of other (macro) organisms.
- This phenomenon of eutrophication has led to the development of tertiary treatment systems.
- In these, nitrogen and/or phosphorus are removed, along with solids and organic materials.
- Primary treatment consists of screens (for removal of floating matter), grit chamber (for removal of inorganic suspended solids) and primary sedimentation tank (for removal residual settleable solids which are mostly organic). Skimming tanks may be used for removal of oils;
- Almost invariably biological methods are used in the treatment systems to effect secondary treatment for removal of organic material. In biological treatment systems, the organic material is metabolized by bacteria. Depending upon the requirement for the final effluent quality, tertiary treatment methods and/or pathogen removal may be included.

CHAPTER-2

INTRODUCTION TO WASTEWATER TREATMENT

X

WHAT IS DOMESTIC WASTEWATER?

- Waste water produced due to human activities in households and offices is called domestic waste water i.e. waste water from the kitchen, washbasin, toilet, shower and laundry is called domestic waste water

DEFINITION OF DIFFERENT TYPES OF DOMESTIC WASTEWATER

- Yellow Water : Human Urine
- Brown Water : Human Faeces with flux water (Included Toilet Paper)
- Black Water : Human Faeces (Brown Water) mixed with urine water (Yellow Water) i.e. Wastewater from toilet
- Grey Water: water used in kitchen, bathroom including sinks, baths, showers and laundry i.e. Water then be used at house except water from toilet

COMPONENTS PRESENT IN DOMESTIC WASTE WATER

Component	Of special interest	Environmental effect
Microorganisms	Pathogenic bacteria, virus and worms eggs	Risk when bathing and eating shellfish
Biodegradable organic materials	Oxygen depletion in rivers and lakes	Fish death, odours
Other organic materials	Detergents, pesticides, fat, oil and grease, colouring, solvents, phenols, cyanide	Toxic effect, aesthetic inconveniences, bioaccumulation in the food chain
Nutrients	Nitrogen, phosphorus, ammonium	Eutrophication, oxygen depletion, toxic effect
Metals	Hg, Pb, Cd, Cr, Cu, Ni	Toxic effect, bioaccumulation
Other inorganic materials	Acids, for example hydrogen sulphide, bases	Corrosion, toxic effect
Thermal effects	Hot water	Changing living conditions for flora and fauna
Odour (and taste)	Hydrogen sulphide	Aesthetic inconveniences, toxic effect
Radioactivity	Radon	Highly toxic, cancerous

Table : 2.1

CHARACTERISTICS OF DOMESTIC WASTE WATER

- Bacteria, fungi, protozoa, and algae. Plants include ferns, mosses, seed plants and liverworts. Physically, domestic wastewater is usually characterized by a grey colour, musty odor and has a solids content of about 0.1%.
- The solid material is a mixture of faeces, food particles, toilet paper, grease, oil, soap, salts, metals, detergents, sand and grit.
- The solids can be suspended (about 30%) as well as dissolved (about 70%).
- Biologically, wastewater contains various microorganisms but the ones that are of concern are those classified as protista, plants, and animals.
- Chemically, wastewater is composed of organic (70%) and inorganic (30%) compounds as well as variousgases.
- Organic compounds consist primarily of carbohydrates (25 %), proteins (65 %) and fats (10 %), which reflects the diet of the people.
- Inorganic components may consist of heavy metals, nitrogen, phosphorus, pH, sulphur, chlorides, alkalinity, toxic compounds, etc.
- However, since wastewater contains a higher portion of dissolved solids than suspended, about 85 to 90% of the total inorganic component is dissolved and about 55 to 60% of the total organic component is dissolved.
- Gases commonly dissolved in wastewater are hydrogen sulphide, methane, ammonia, oxygen, carbon dioxide and nitrogen.
- The first three gases result from the decomposition of organic matter present in the wastewater.

CHARACTERISTICS OF WASTEWATER

Solids:

- Other than gases, all contaminants of water contribute to the solids content, which is composed of floating matter, settleable matter, colloidal matter and matter in solution.
- Solids typically include inorganic matter such as silt, sand, gravel, and clay, and organic matter such as plant fibers and microorganisms from natural and man-made sources.
- Other important physical characteristics include particle size distribution, turbidity, color, transmittance, temperature, conductivity, density, specific gravity and specific weight.
- Odor, sometimes considered to be a physical factor. In regards to size, solids in wastewater can be classified as suspended, settleable, colloidal, or dissolved.
- They are also characterized as being volatile or non-volatile
- The various solids classifications are identified in Table. 2.2

TEST	DESCRIPTION
TOTAL SOILDS (TS) TS= (M1 -M2)/V M1= MASS OF CRUCIBLE DISH AFTER DRYING AT 105 C M2=MASS OF INITIAL CRUCIBLE DISH V=VOLUME OF SAMPLE	THE RESIDUALS REMAINING AFTER A WASTE WATER SAMPLE HAS BEEN EVAPORATED AND DRIED AT A SPECIFIED TEMPERATURE (103 -105 ?C)
TOTAL VOLATILE SOLIDS (TVS) VS=(M1 -M3)/V M1= MASS OF CRUCIBLE DISH AFTER DRYING AT 105 C M3=MASS OF CRUCIBLE DISH AFTER IGNITION AT 550 C V=VOLUME OF SAMPLE	THOSE SOLIDS THAT CAN BE VOLATILIZED AND BURNED OFF WHEN THE TS ARE IGNITED (500 ± 50 ? C)
TOTAL FIXED SOLIDS (TFS)	THE RESIDUES THAT REMAINS AFTER TS ARE IGNITED (500 ± 50 ? C)
TOTAL SUSPENDED SOLIDS (TSS) SS=(M4 -M5)V M4= MASS OF FILTER AFTER DRYING AT 105 C M6=MASS OF FILTER AFTER IGNITION AT 550 C V=VOLUME OF SAMPLE	PORTION OF THE TS RETAINED ON A FILTER WITH A SPECIFIED PORE SIZE, MEASURED AFTER BEING DRIED AT A SPECIFIED TEMPERATURE (105 ? C).
VOLATILE SUSPENDED SOLIDS (VSS) VSS=(M4 -M6)/V M4= MASS OF FILTER AFTER DRYING AT 105 C M6=MASS OF FILTER AFTER IGNITION AT 550 C V=VOLUME OF SAMPLE	THOSE SOLIDS THAT CAN BE VOLATIZED AND BURNED OFF WHEN THE TSS ARE IGNITED (500 ± 50 ? C)
FIXED SUSPENDED SOLIDS (FSS)	THE RESIDUE THAT REMAIN AFTER TSS ARE IGNITED (500 ± 50 ? C)
TOTAL DISSOLVED SOLIDS (TDS)	THOSE SOLIDS THAT PASS THROUGH THE FILTER, AND ARE THAN EVAPORATED AND DRIED AT SPECIFIED TEMPERATURE . IT SHOULD BE NOTED THAT WHAT IS MEASURED AS TDS IS COMPRISED OF COLLOIDAL AND DISSOLVED SOLIDS. COLLOIDS ARE TYPICALLY IN SIZE RANGE FROM 0.001 -1 μM.
TOTAL VOLATILE DISSOLVED SOLIDS (VDS)	THOSE SOLIDS THAT CAN BE VOLATILIZED AND BURNED OFF WHEN THE TDS ARE IGNITED (500 ± 50 ? C)
FIXED DISSOLVED SOLIDS (FDS)	THE RESIDUE THAT REMAIN AFTER TDS ARE IGNITED (500 ± 50 ? C)
SETTLEABLE SOLIDS	SUSPENDED SOLIDS, EXPRESSED AS MILLILITERS PER LITTER THAT WILL SETTLE OUT OF SUSPENSION WITHIN A SPECIFIED PERIOD OF TIME.

Table : 2.2

INTERRELATIONSHIPS OF SOLIDS FOUND IN WATER AND WASTEWATER

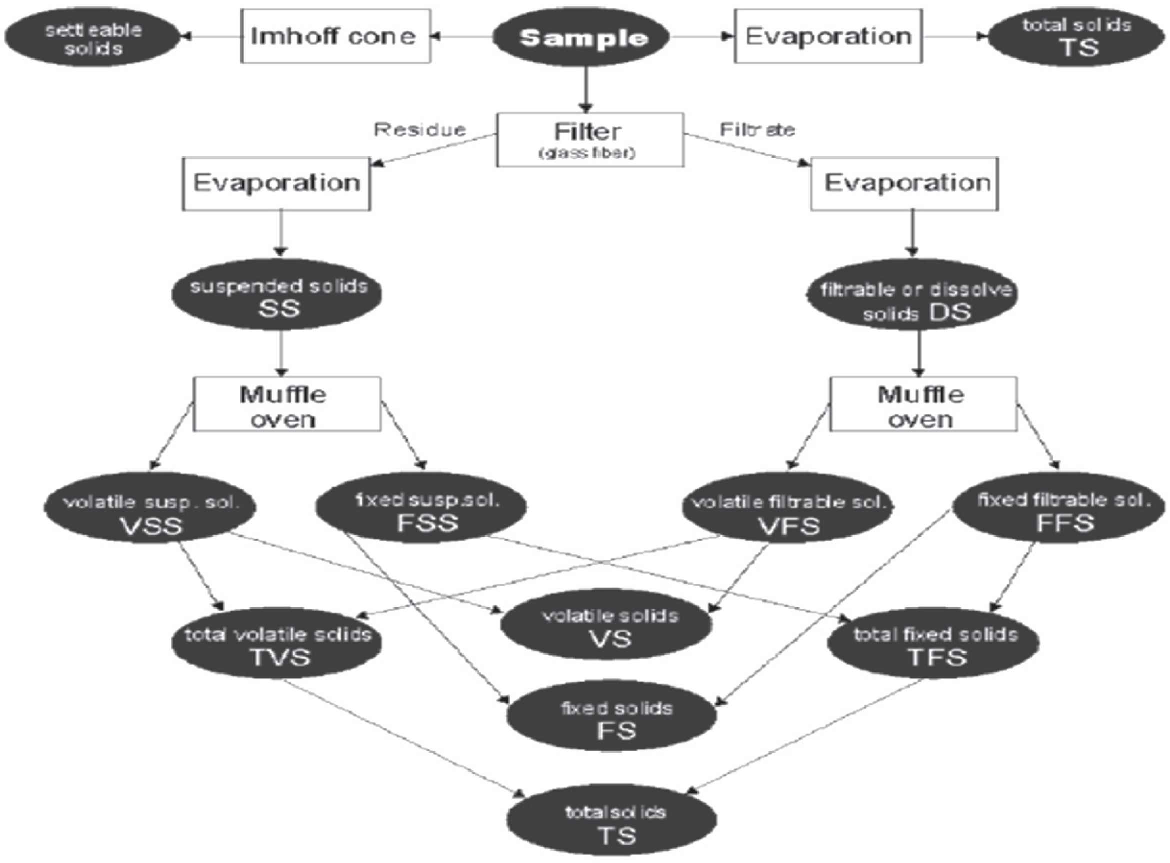


Fig. : 2.1

Gases:

- Gases commonly found in untreated wastewater include nitrogen (N_2), oxygen(O_2), carbon dioxide (CO_2),hydrogen sulfide(H_2S), ammonia (NH_3), and methane (CH_4).
- The first three are common gases of the atmosphere and will be found in all waters exposed to air.
- The latter three are derived from the decomposition of the organic matter present in waste water and dangerous to worker's health and safety.
- Although not found in untreated waste water, other gases with which the environmental engineer must be familiar include chlorine (Cl_2), ozone (O_3) and the oxides of sulfur and nitrogen.

SOLUBILITY OF GASES IN WATER :

- The actual quantity of a gas that can be present in solution is governed by :-
  (1) the solubility of the gas as defined by henry's law
  (2) the partial pressure of the gas in the atmosphere
  (3) the temperature
  (4) the concentration of the impurities in the water.

  Henry's law:
  $p=k_hC$

  k_h=henry's constant
  C=concentration of solute in solution
  p= partial pressure of solute in the solution

CHAPTER-3

WATER AND WASTEWATER PARAMETERS

PHYSICAL PARAMETERS

Turbidity :

- Turbidity, a measure of the light-transmitting properties of water.
- The measurement of turbidity is based on comparison of the intensity of light scattered by a sample to the light scattered by a reference suspension under the same condition.
- Turbidity measurement are reported as nephelometric turbidity unit (NTU).
- If ultraviolet radiation (UV) is used for disinfection of treated wastewater, turbidity measurement will be important because for UV to be effective in disinfecting wastewater effluent, UV light must be able to penetrate the stream flow.
- There is no relationship between turbidity and the concentration of total suspended solids in untreated wastewater. Both the size and surface characteristics of the suspended material influence absorption and scattering.
- One of the problems with the measurement of turbidity (especially in low filtered effluent) is the high degree of variability observed, depending on the light source (incandescent light versus light-emitting diodes) and method of the measurement (reflected versus transmitted light).

Color :

- In wastewater treatment, colour is not necessarily a problem, but instead is a indicator of the condition of the wastewater.
- fresh wastewater is usually a light brownish-gray colour The colour of wastewater changes sequentially from grey to dark grey and ultimately to black as the travel time in collection system increases (flow becomes increasingly more septic) and more anaerobic conditions develop..
- If the colour of waste water is black, the waste water is septic.
- Some industrial waste water may also add colour to domestic water.
- Gray, dark gray, and black colour of the waste water is due to the formation of metallic sulfides.
- Sulfide is produced under anaerobic conditions reacts with the metals in the waste water.

Temperature :

- Temperature is very important parameter because of its effect on chemical reactions on reaction rates, aquatic life, and the solubility of essential gases such as oxygen in water.
- The temperature of waste water is commonly higher than that of the local water supply.
- It is due to addition of warm water from household and industrial activities.

Effects of temperature :

- Oxygen is less soluble in warm water than in cold water
- A sudden change in temperature can result in a high rate of mortality of aquatic life.

Odour :

- In wastewater, odours are of major concern, especially to those who reside in close proximity to a wastewater treatment plant. These odours are generated by gases produced by decomposition of organic matter or by substances added to the wastewater. Odour from fresh wastewater is less objectionable than the odour from wastewater that has undergone anaerobic decomposition.
- The most characteristic odour of stale or septic wastewater is that of hydrogen sulphide (H_2S), which is produced by anaerobic microorganisms that reduce sulphate to sulphide. The malodorous compounds responsible for producing objectionable odours in water can be detected by diluting a sample with odour free water until the least detectable odour level is achieved. This is recorded as TON (Threshold Odour Number).
- The concentration of malodorous gases such as hydrogen sulphide, ammonia, mercaptans etc. emitted into the air from wastewater can be measured by any commercially available gas monitor.

Conductivity :

- Electrical conductivity of a water is used to determine the suitability of a water for irrigation.
- SI units of electrical conductivity : Millisiemens per meter (mS/m) and in US : Micromhos per centimeter (µmho/cm).

Density, Specific Gravity and Specific Weight :

- The density of waste water ρ is defined as its mass per unit volume expressed as g/L or kg/m^3 in SI units.
- Density of waste water forms density currents in sedimentation tank, chlorine contact tank, and other treatment units.
- Both the density and specific gravity of waste water are temperature- depended.
- Vary with the concentration of total solids in the waste water .

➢ CHEMICAL PROPERTIES

- The chemical constituents of waste water: inorganic, organic matter.
- Organic matter in waste water classified as aggregate and individual.
- Inorganic nonmetallic and metallic constituents in waste water derived from:
- Background level in the water supply
- Additional resulting from domestic use,
- Additions of highly mineralized water from private wells and ground water,
- Industrial use.
- Inorganic nonmetallic constituents includes : pH, nitrogen, phosphorus, alkaline, chloride, sulfur, gases and odour.

pH :

- pH is defined as the negative logarithm of hydrogen ion concentration.
- Expressing hydrogen ion concentration.
- $pH=-log_{10}[H^+]$
- The concentration range suitable for the exitenence of most biological life is quite narrow and critical.
- Allowable pH range of effluent usually varies from 6.5-8.5 to protect organisms.
- pOH is defined as the negative logarithm of the hydroxyl-ion concentration.
- pH + pOH = 14

Chlorides :

- Domestic wastewater is a rich source of chlorides, because human excreta, mainly urine, is rich in chloride. It does not present a major pollution threat. But, Chloride ion concentration is an important factor to be considered if treated effluent is used for irrigation. High chloride concentration disturbs the osmotic balance between the plants and the soil, which affects the growth of the plants.
- In waste water can impact the final reuse application's of treated waste water. Chlorides in natural water result from the leaching of chloride-containing rocks and soils with which the water comes in contact in costal area.
- Agricultural, industrial and domestic waste waters discharged to surface waters are a source of chlorides.

Alkalinity :

- Alkalinity is the capacity of water to neutralise acids.
- Alkalinity in waste water results from the presence of hydroxides $[OH^-]$, carbonates$[CO_3^-]$, and bicarbonates $[HCO_3^-]$ of elements such as calcium, magnesium, sodium,potassium or ammonia.
- Calcium and magnesium bicarbonates are most alkaline.
- For most practical purposes alkalinity can be defined in terms of molar quantities.
- Alkalinity plays an important role in the treatment of wastewater, as it indicates the buffer capacity of water. This affects the growth and activity of microbes present in activated sludge, which are responsible for the treatment of wastewater. It is also an essential parameter to be estimated to design and implement the corrosion and odourcontrol processes.

Dissolved Oxygen (DO) :

- Dissolved oxygen is the amount of molecular oxygen dissolved in water. It is required for the respiration of aerobic microorganisms. However, oxygen is only slightly soluble in water. The actual quantity of oxygen (other gases too) that can be present in solution is governed by:
- The solubility of gas
- The partial pressure of the gas in the atmosphere
- The temperature
- The concentration of the impurities in the water (e.g., Salinity, suspended solids, etc.) The amount of do decreases with increasing water temperature. So a cool or cold water can contain much more do than the warm water. As a result, aquatic life in streams and lakes is placed under more oxygen stress during summer months than during the other seasons.

Nitrogen :

- The elements nitrogen and phosphorous is essential to the growth of microorganisms, plants and animals.
- known as nutrients or biostimulants.
- Trace quantities of other elements such as iron, are also needed for biological growth but nitrogen and phosphorous, are the major nutrients.
- Nitrogen is an essential building block in the synthesis of protein.
- Nitrogen data will be required to evaluate the treatability of waste water by biological processes.
- Insufficient nitrogen can necessitate the addition of nitrogen to make the waste treatable.

Source of Nitrogen :

(1) the nitrogenous compounds of plant and animals origin

(2) Sodium nitrate and

(3) Atmospheric nitrogen

- Nitrogen compounds with environmental relevance frequently analyzed in wastewater are ammonia, nitrite, nitrate, and Kjeldahl nitrogen. Ammonia discharged to surface water can be nitrified in the aqueous environment if nitrifying microorganisms are present. The nitrifying bacteria consume dissolved oxygen for this process, thus depleting the oxygen content of the surface water with the consequence of massive dying of fish. Moreover, if the pH of the surface water is in the alkaline range, NH_3 is formed which is toxic towards fish.
- The nitrate ion represents a nutrient leading to eutrophication of surface water, and nitrite is toxic and can react with amines (formed e.g. from amino acids of proteins) to yield N-nitosoamines which represent powerful carcinogens. Kjeldahl nitrogen is a sum parameter of compounds containing the nitrogen atom with an oxidation number of -3 (ammonia, amines and many other organic nitrogen compounds). It thus comprises organic nitrogen compounds besides ammonia nitrogen. This is also an important nitrogen parameter, because organic nitrogen compounds can be metabolized to ammonia (this conversion can also take place in surface water).

Nitrogen Pathways in Nature :

- The nitrogen present in fresh wastewater is primarily combined in proteinaceous matter and urea.
- Decomposition by bacteria readily changes the organic form to ammonia.
- The age of wastewater is indicated by the relative amount of ammonia that is present.
- In an aerobic environment, bacteria can oxidize the ammonia nitrogen to nitrites and nitrates.

Phosphorus :

- Phosphorus is essential to the growth of algae and other biological organisms. Municipal wastewater may contain 4 to 16 mg/l of phosphorus as.
- The usual forms of phosphorus include the orthophosphate, polyphosphate and organic phosphate.
- The amount of phosphorus compounds present in wastewater discharge has to be controlled in order to avoid noxious algal blooms occurred in surface water.
- The sum of all three phosphorus species is designated as total phosphorus.

Sulfur :

- The sulfate ion occurs naturally in most water supplies and in wastewater as well.
- Sulfur is required in the synthesis of proteins and it is released in their degradation.
- Sulfate is reduced biologically under anaerobic conditions to sulfide which, can combine with hydrogen to form hydrogen sulfide (H_2S).
- Hydrogen sulfide gas, which will diffuse into the headspace above the wastewater in sewers that are not flowing full, tends to collect at the crown of the pipe.
- The accumulated H_2S can be oxidized biologically to sulfuric acid, which is corrosive to concrete sewer pipes.
- This corrosive effect, known as "crown rot", can seriously threaten the structural integrity of the sewer pipe.
- Sulfates are reduced to sulfides in sludge digesters and may upset the biological process if the sulfide concentration exceeds 200mg/l.
- The H_2S gas, which is evolved and mixed with the wastewater gas (CH_4 + CO_2), is corrosive to the gas piping and, if burned in gas engines, the products of combustion can damage the engine and severely corrode exhaust gas heat recovery equipment, especially if allowed to cool below the dew point.

Oil and Grease :

- The term oil and grease, includes the fats, oils, waxes, and other related constituents found in waste water.
- It causes scum in aeration basins of activated sludge plants, which interferes with the biological oxidation of wastes and produces a low quality settling sludge.
- Oil and grease are chemically similar they are compounds of alcohol or glycerol with fatty acids.
- The glyceride of fatty acids that are liquid are called oil and those are solids are called grease.
- Adsorbable organic halides (AOX) is an organic sum parameter comprising such organics that contain chlorine, bromine or iodine (not fluorine!) atoms and are adsorbable to activated carbon.

Metallic Constituents :

- Trace quantities of many metals, such as cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), and zinc (Zn) are important constituents of waste waters.
- Many of this metals are also classified as priority pollutants.

Source of Metals:

The source of trace metals in waste water include :

- discharges from residential dwellings,
- ground water infiltration.
- commercial and industrial discharges.
- Cadmium, chromates, lead, and mercury are often present in industrial wastes.
- Fluoride, a toxic anion is found commonly in waste water from electronics manufacturing facilities.

CHAPTER-4

WASTEWATER ORGANIC & BIOLOGICAL CONSTITUENTS

➢ AGGREGATE ORGANIC CONSTITUENTS

- Over the years a number of different analysis have been developed to determine organic content of wastewater.
- In general, the analysis may be classified into : Organic matter comprising, a number of organic constituents with similar characteristics.
- And those analysis used to quantify individual organic compounds.

Measurement of Organic Content :

- Laboratory methods commonly used today to measure gross amounts of organic matter waste water include :-
  (1) biochemical oxygen demand (BOD)
  (2) chemical oxygen demand (COD)
  (3) total organic carbon (TOC)
- Biochemical Oxygen Demand is a sum parameter and the amount of oxygen required to oxidise organic matter present in the water biochemically. So BOD is an indirect measure of the concentration of organic contamination in water.

1) BOD (Biochemical Oxygen Demand) :

- BOD is the most widely used parameter of organic pollution applied to wastewater and is used:-
- To determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present,
- To determine the size of wastewater treatment facilities,
- To measure the efficiency of some treatment processes;
- To determine compliance with wastewater discharge permits.

Basis for BOD Test :

- If sufficient oxygen is available, the aerobic biological decomposition of an organic waste will continue until all of the waste is consumed.
- Three more or less distinct activities occur.
- A portion of a waste is oxidized to end products to obtain energy for cell maintenance and the synthesis of new cell tissue.
- Some of the waste is converted into new cell tissue using part of the energy released during oxidation.
- When the organic matter is used up, the new cell begin to consume their own cell tissue to obtain energy for cell maintenance. This third process is called endogenous respiration.

2) COD (Carbonaceous Biochemical Oxygen Demand) :

- When nitrification occurs, measured BOD value will be higher than true value due to oxidation of carbonaceous material. If a given percentage of carbonaceous biochemical oxygen demand (CBOD) removal must be achieved to meet regulatory permit limits, early nitrification can pose a serious problem.
- The effect of nitrification can be overcome either by using various chemical to suppress the nitrification reaction, or by treating the sample to eliminate the nitrifying organisms.
- The equivalent amount of oxygen required to oxidise organic matter present in a water sample by means of a strong chemical oxidising agent is called chemical oxygen demand (COD). COD is also a sum parameter and is used to measure the content of organic matter of wastewater. The COD values include the oxygen demand created by biodegradable as well as non-biodegradable substances. As a result, COD values are greater than BOD
- Once the correlation has been established, COD measurements can be used to good advantage for treatment-plant control and operation.

3) TOC (Total Organic Carbon) :

- Wastewater content of carbon bound in organic molecules is the TOC (total organic carbon). Organic carbon comprises nearly all carbon compounds except a few carbon species which are looked at as inorganic (carbon dioxide, hydrogen carbonate, carbonate, cyanide and some further examples which are not commonly found in wastewaters).

BOD-COD-TOC Comparison Ratios :

- Typical value for the ratio of BOD/COD for untreated municipal waste water are in the range from 0.3 to 0.8.
- If the BOD/COD ratio for untreated wastewater is 0.5 or greater, the waste is considered to be easily treated by biological means.
- If the ratio is below 0.3, either the waste may have some toxic components or acclimated microorganisms may be required in its stabilization.
- The corresponding BOD/TOC ratio for untreated wastewater varies from 1.2 to 2.0. In using these ratios it important to remember that they will change significantly with the degree of treatment the waste has undergone, as reported in Table.

MEASURES OF VARIOUS PARAMETERS

Parameter	Measures to be taken
turbidity	immediate inspection and documentation; analytical quantification should be carried out on the same day
settleable solids	immediate analysis using Imhoff cone
suspended solids	filtration and gravimetric analysis must be performed as soon as possible
colour	immediate inspection and documentation
odor	immediate check and documentation
concentration of dissolved oxygen	analysis with oxygen probe
pH	analysis with pH probe
conductivity	analysis with conductivity probe
nitrite	transport samples as fast as possible to laboratory for analysis; reflectometric analysis at sampling location
temperature	directe determination in the wastewater

Table : 4.1 Measures Of Various Parameters

COMPARISON OF RATIOS OF VARIOUS PARAMETERS USED TO CHARACTERIZE WASTEWATER

Type of wastewater	BOD/COD	BOD/TOC
Untreated	0.3 – 0.8	1.2 - 2.0
After primary settling	0.4 – 0.6	0.8 - 1.2
Final effluent	0.1 – 0.3	0.2 - 0.5

Table : 4.2 Comparison of Ratios of Various Parameters Used To Characterize Wastewater

➢ BIOLOGICAL CHARACTERISTIC

- The biological characteristics of wastewater are important
- In the control of diseases caused by pathogenic organism of human origin
- It is due to the extensive and fundamental role played by bacteria and other microorganisms in the decomposition and stabilization of organic matter.
- Microorganisms found in surface waters and Wastewater include :
- Organisms found in surface water and wastewater include bacteria, fungi, algae, protozoa, plants & animals and viruses,
- Bacteria, fungi, algae, protozoa, and viruses can only be observed microscopically.

General Classification :

- Living single-cell microorganisms that can only be seen with a microscope are responsible for the activity in biological wastewater treatment.

Pathogenic Organisms :

- The principal pathogenic organisms found in untreated wastewater are as per table along with the diseases and diseases symptoms associated with each pathogen.
- Bacterial pathogenic organisms of human origin typically cause diseases of the gastrointestinal tract, such as typhoid and paratyphoid fever, dysentery, diarrhea, and cholera.

Analysis Of Wastewater Flow Rate Data :

- Because the hydraulic design of the collection and treatment facilities is affected by variations in wastewater flow rates, the flow rate characteristics have to be analyzed carefully from existing records.

Variations In Wastewater Flow Rates :

- Wastewater flow rates vary during the time of the day, day of the week, season of the year, or depending upon the mature of the dischargers to the collection type.
- Minimum flows occur during the early morning hours when water consumption is lowest and when the base flow consists of infiltration and small quantities of sanitary wastewater.

CHAPTER-5

DOMESTIC WASTEWATER SAMPLING

➢ SAMPLING

- Representative sampling of wastewater streams is decisive for correct modelling of wastewater treatment processes.
- While in laboratories usually high efforts are made to execute chemical analyses of wastewater samples with high accuracy, wastewater sampling is sometimes carried out by people who are not trained in sampling. Thus, experts assume that errors in wastewater analyses caused by mistakes during sampling are several orders of magnitude higher than by analytical errors in the chemical laboratory.
    - Sampling programs are undertaken for a variety of reasons such as to obtain :-
    - Routine operating data on overall plant performance.
    - Data that can be used to document the performance of a given treatment operation or process.
    - Data that can be used to implement proposed new programs/projects and
    - Data needed for reporting regulatory compliance.

To Meet The Goals Of The Sampling Program, The Collected Sample Must Be :

- Representative:
  The data must represent the wastewater or environment being sampled.
- Reproducible:
  The data obtained must be reproducible by other following the same sampling and analytical protocols.
- Defensible:
  Documentation must be available to validate the sampling procedures. The data must have a *known degree of accuracy and precision.*
- Useful:
  The data can be used to meet the objectives of monitoring on going plant/plannedproject.

Sampling Plan :

Number of sampling locations, number and type of samples, time intervals. (e.g., real time and/or time-delayed samples.)

Sample Types And Size :

- Different kinds of sampling are possible.
- Both kinds of sampling can either be carried out manually or automatically. Automatic samplers are being used increasingly. They are effective and reliable and can significantly increase the frequency of sampling. Especially for composite samples taken during long periods (days, weeks), automatic samplers are convenient and help to save manpower.

Sample Labeling And Chain Custody :

- Sample labels, sample seals, field log book, chain of custody record, sample analysis request sheets, sample delivery to laboratory, receipt and logging of sample and assignment of sample for analysis.

Sampling Methods :

Specific techniques and equipment to be used (e.g., manual, automatic or sorbent sampling).

Sampling Storage And Preservation :

Types of containers (e.g., glass or plastic), preservation methods, maximum allowable holding times.

Sample Constituents :

A list of the parameters to be measured.

Analytical Methods :

- A list of the field and laboratory test methods and procedures to be used and the detection limits for the individual methods.
- Parameters which cannot be stabilized by sample preservation and have to be measured immediately after sampling at the sampling location or directly in the wastewater.
- Each step of handling the samples has to be documented in the sampling protocol which should also contain :
- The sample designation (which has to be marked also on the sample container),
- Date and day time of sampling,
- Sampling location,
- Name of person collecting the samples,
- Purpose of sampling, mode of sampling (grab or composite sample etc.),
- Results of measurements performed at the sampling site,
- Sample preparation measures (e.G. Sedimentation of sample),
- Preservation procedure(s),
- Sample storing conditions until delivery to laboratory, comments upon reference samples simultaneously collected,
- Comments about subsequent changes occurring in the sample,
- Comments about deviations from routinely performed sampling (e.g. Application of another automatic sampler,
- More frequent transfers of samples to other bottles than usually done),
- Observations at sampling site (weather, wastewater irregularities as foam, bulking sludge, odor etc.),
- Comments about irregularities observed on the sampling site (e.g. Construction operations within a treatment plant etc.).
- Sampling documentation forms can serve as check lists. For further analyses in the laboratory, samples must be transported as soon as possible to the laboratory. For keeping the samples unchanged during the transport, the sample containers should be tightly sealed, kept cool (e.g. using a cooling bag - which should be exclusively used for sampling but not for food transport for safety reasons) and dark.
- In vehicles used for sample transport, samples must be protected against being tilt over. If samples are shipped by mail or express services, by railway, ship or aero plane, special safety measurements have to be taken. The bottles must be sealed absolutely tight and protected against shock in order to avoid leakages of the sample bottles.

- The samples as well as the sampling protocols have to be received by the laboratory staff in a responsible manner because of registration and eventual transfer of some samples to other laboratories for special analyses. Working safety has to be obeyed not only in laboratories, but also during sampling.
- It is clear that sampling of wastewater (and also of other media) has to be carefully prepared (providing sampling equipment like suitable sample bottles in sufficient number etc.). There must be a good communication between sampling staff and the analytical laboratory concerning number of samples, parameters which must be analyzed, time of delivery of samples to the laboratory, because the laboratory has to organize the enforcement of the analyses as well as to provide storing space in refrigerators or freezers.

Sampling As A Tool For Controlling Of Process Of A Wastewater Treatment Plant :

- Some parameters for controlling the process of the activated sludge system are pH, dissolved oxygen concentration (DO) and acid capacity with electrodes.
- The pH value and acid capacity are often used for dosage of liquids to stabilize the activated sludge process. The concentration of dissolved oxygen is used to control the activity of the aeration system. If the aeration system produce more oxygen than the process needs, the operation costs increase.
- At effluent point of aeration tank, a grab sample will be taken directly out of the aeration tank to determine the concentration of the mixed liquor suspended solids (MLSS) and the sludge volume index (SVI).

Some Hints For Taking Samples :

- Use a clean glass or plastic bottle for samples
- Label a bottle (e.g. point and kind of sampling, date and time, name of sample collector, parameters of analyses).
- Do not touch the inner of the bottle with your fingers (contamination).
- Through the first flush out of a pipe away and than take your sample.
- Stir the sample before you fill it into the flask.
- Fill the bottle up to the top. Oxygen in the flask let continue a biological process and the concentration of ammonium will decrease and the concentration of nitrate will increase.
- Take care that the volume of the samples will be big enough for analyses.
- Carry the sample as soon as possible to the laboratory or analyse it onsite (biological degradation still takes place!).
- Cool the sample, do not leave it in the sun.
- Sample should be stirred, homogenized or filtrated before you start the analyse (depends on the kind of parameter for analyses).
- Check and clean automatically working sampling units frequently.
- Control the cooling system (wrong temperature will change the ingredients.
- Take care that the whole volume of the connected samples will not be bigger that the volume of the flask.

APPENDIX

Determination	Sample size mL	Preservation	Storage recommended/ Regulatory (1)
Acidity	100	Refrigerate	24 h / 14 d
Alkalinity	200	Refrigerate	24 h / 14 d
BOD	1000	Refrigerate	6 h / 48 h
Carbon, organic, total	100	Analyze immediately or refrigerate and add HCl to pH<2	7 d / 28 d
Carbon dioxide	100	Analyze immediately	Stat/ N.S.
COD	100	Analyze as soon as possible or add H_2SO_4 to pH<2, refrigerate	7 d / 28 d
Chlorine, residual	500	Analyze immediately	0.5 h / Stat
Color	500	Refrigerate	48 h / 48 h
Conductivity	500	Refrigerate	28 d / 28 d
Fluoride	300	None required	28 d / 28 d
Hardness	100	Add HNO_3 to pH<2	6 months
		For dissolved metals filter immediately, add HNO_3 to pH<2	6 months / 6months
Ammonia	500	Analyze as soon as possible or add H_2SO_4 to pH<2, refrigerate	7 d / 28 d
		Add H_2SO_4 to pH<2, refrigerate	None / 28 d
Organic Kjeldahl	300	Refrigerate, add H_2SO_4 to pH<2	7 d / 28 d
Oil and grease	1000	Add H_2SO_4 to pH<2, refrigerate	28 d / 28 d
Oxygen, dissolved:	300		
		Add H_2SO_4	2 h / Stat.
Phosphate	100	For dissolved phosphate filter immediately; refrigerate	48 h / N.S.

Salinity	240	Analyze immediately or use wax seal	6 months / N.S.
Sludge digester gas	-	-	28 d / 28 d
Solids	-	Refrigerate	7 d / 2 -7 d see cited reference
Sulfate	-	Refrigerate	28 d / 28 d
Sulfide	100	Refrigerate, add 4 drops 2N zinc acetate/100 mL, add NaOH to pH>9	28 d / 7 d
Taste	500	Analyze as soon as possible, refrigerate	24 h / N.S.
Temperature	-	Analyze immediately	Stat. / Stat.
Turbidity	-	Analyze same day; store in dark up to 24 h, refrigerate	24 h / 48 h

Table : 5.1

CHAPTER-6

QUANTITY ESTIMATIONS OF SEWAGE

INTRODUCTION

- The sewage collected from the municipal area consists of wastewater generated from the residences, commercial centers, recreational activities, institutions and industrial wastewaters discharge into sewer network from the permissible industries located within the city limits.
- Accurate estimation of sewage discharge is necessary for hydraulic design of the sewers.
- Actual measurement of the discharge is not possible if the sewers do not exist..

SOURCES OF SANITARY SEWAGE :

- Water supplied by water authority for domestic usage, after desired use it is discharged in to sewers as sewage.
- Water supplied to the various industries for various industrial processes by local authority.
- Some quantity of this water after use in different industrial applications is discharged as wastewater.
- The water supplied to the various public places such as, schools, cinema theaters, hotels, hospitals, and commercial complexes.
- Part of this water after desired use joins the sewers as wastewater.
- Water drawn from wells by individuals to full fill domestic demand.
- After uses this water is discharged in to sewers.
- The water drawn for various purposes by industries, from individual water sources such as, wells, tube wells, lake, river, etc.
- Fraction of this water is converted into wastewater in different industrial processes or used for public utilities within the industry generating wastewater.
- This is discharged in to sewers.
- Infiltration of groundwater into sewers through leaky joints.
- Entrance of rainwater in sewers during rainy season through faulty joints or cracks in sewers.

DRY WEATHER FLOW :

- Dry weather flow is the flow that occurs in sewers in separate sewerage system or the flow that occurs during dry seasons in combined system.
- This flow indicates the flow of sanitary sewage.
- This depends upon the rate of water supply, type of area served, economic conditions of the people, weather conditions and infiltration of groundwater in the sewers, if sewers are laid below groundwater table.

Evaluation of Sewage Discharge :

- Correct estimation of sewage discharge is necessary; otherwise sewers may prove inadequate resulting in overflow or may prove too large in diameter, which may make the system uneconomical and hydraulically inefficient.
- Hence, before designing the sewerage system it is important to know the discharge / quantity of the sewage, which will flow in it after completion of the project and at the end of design period.
- Apart from accounted water supplied by water authority that will be converted to wastewater, following quantities are considered while estimating the sewage quantity

ADDITION DUE TO INFILTRATION :

- This is additional quantity due to groundwater seepage in to sewers through faulty joints or cracks formed in the pipes.
- The quantity of the water depends upon the height of the water table above the sewer invert level.
- If water table is well below the sewer invert level, the infiltration can occur only after rain when water is moving down through soil.
- Quantity of the water entering in sewers depends upon the permeability of the ground soil and it is very
- Difficult to estimate.
- While estimating the design discharge, following suggested discharge can be considered.
- Table given below Suggested estimates for groundwater infiltration for sewers laid below groundwater table

Unit	Minimum	Maximum
L/ha.d	5000	50000
L/km.d	500	5000
L per day per manhole	250	500

Table : 6.1

- Storm water drainage may also infiltrate into sewers.
- This inflow is difficult to calculate. Generally, no extra provision is made for this quantity.
- This extra quantity can be taken care of by extra empty space left at the top in the sewers, which are designed for running ¾ full at maximum design discharge.
- **Net quantity of sewage:** The net quantity of sewage production can be estimated by considering the addition and subtraction as discussed above over the accounted quantity of water supplied by water authority as below:

Net quantity of sewage = Accounted quantity of water supplied from the water works + Addition due to unaccounted private water supplies + Addition due to infiltration – Subtraction due to water losses – Subtraction due to water not entering the sewerage system

Generally, 75 to 80% Of accounted water supplied is considered as quantity of sewage produced.

VARIATION IN SEWAGE FLOW

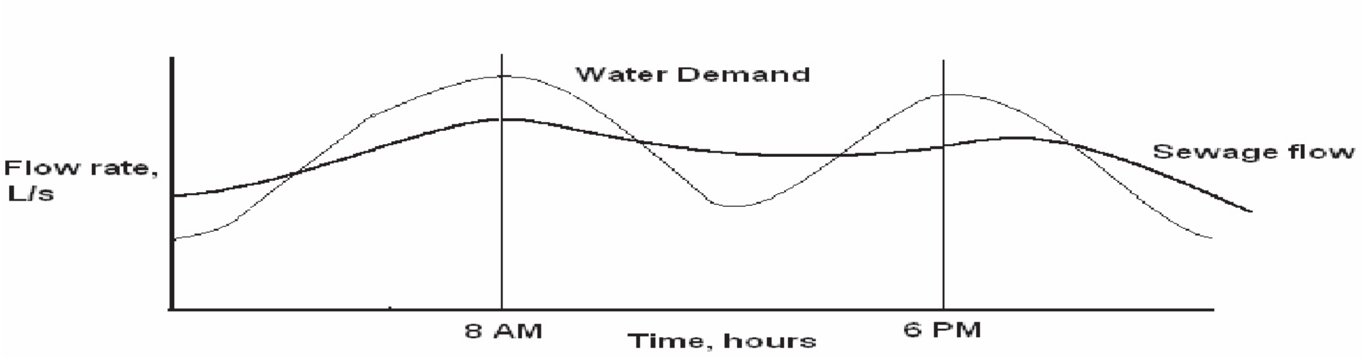


Fig. : 6.1

Typical hourly variations in sewage flow

Maximum daily flow	=	Two times the annual average daily flow (representing
		seasonal variations)
Maximum hourly flow	=	1.5 times the maximum daily flow (accounting hourly
		variations)
	=	Three times the annual average daily flow

Table : 6.2

- As the tributary area increases, peak hourly flow will decrease.
- For smaller population served (less than 50000) the peak factor can be 2.5, and as the population served increases its value reduces.
- For large cities it can be considered about 1.5 to 2.0. Therefore, for outfall sewer the peak flow can be considered as 1.5 times the annual average daily flow.
- Even for design of the treatment facility, the peak factor is considered as 1.5 times the annual average daily flow.
- The minimum flow passing through sewers is also important to develop self cleansing velocity to avoid silting in sewers.
- This flow will generate in the sewers during late night hours. Sewers must be checked for minimum velocity as follows:
- Minimum daily flow = 2/3 Annual average daily flow
- Minimum hourly flow = ½ minimum daily flow
- = 1/3 Annual average daily flow

DESIGN PERIOD

- The future period for which the provision is made in designing the capacities of the various components of the sewerage scheme is known as the design period.
- Following design period can be considered for different components of sewerage scheme.

1.	Laterals less than 15 cm diameter :	Full development
2.	Trunk or main sewers :	40 to 50 years
3.	Treatment Units :	15 to 20 years
4.	Pumping plant :	5 to 10 years

Table : 6.3

DESIGN DISCHARGE OF SANITARY SEWAGE :

- A city has a projected population of 60,000 spread over area of 50 hectare.
- Find the design discharge for the separate sewer line by assuming rate of water supply of 250 LPCD and out of this total supply only 75 % reaches in sewer as wastewater.
- Solution:
- Given data
- Q = 250 lit/capita/day
- Sewage flow = 75% of water supply
- = 0.75* 250
- = 187.5 LPCD
- Total sewage generated = 187.5*60000/(24*3600)= 130.21 lit/sec= 0.13 m^3/s
- Assume peak factor = 2
- Total design discharge = 0.26 m^3/s

CHAPTER-7

SEWER MATERIAL

IMPORTANT FACTORS CONSIDERED FOR SELECTING MATERIAL FOR SEWER

- Following factors should be considered before selecting material for manufacturing sewer pipes:

Resistance to corrosion:

- As sewer carries wastewater that releases gases such as H2S, and this gas in contact with moisture can be converted into sulfuric acid.,
- selection of corrosion resistance material is must for long life of pipe.

Resistance to abrasion :

- Sewage contain considerable amount of suspended solids, part of which are inorganic solids such as sand or grit , which can be result into abrasion that can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough.

Strength and durability

- The sewer pipe should have sufficient strength to withstand all the forces that are likely to come on them.
- They are not subjected to internal pressure of water.
- To withstand external load safely without failure, sufficient wall thickness of pipe or reinforcement is essential.
- In addition, the material selected should be durable and should have sufficient resistance against natural weathering action to provide longer life to the pipe.

Weight of the material

- The material selected for sewer should have less specific weight, which will make pipe light in weight.

Imperviousness :

- To eliminate chances of sewage seepage from sewer to surrounding, the material selected for pipe should be impervious.

Economy and cost :

- Sewer should be less costly to make the sewerage scheme economical.

Hydraulically efficient :

- The sewer shall have smooth interior surface to have less frictional coefficient.

MATERIALS FOR SEWERS

ASBESTOS CEMENT SEWERS

Advantages :

- These pipes are light in weight and hence, easy to carry and transport.
- Interior is smooth (n = 0.011) hence, can make excellent hydraulically efficient sewer.

Disadvantages :

- These pipes are structurally not very strong.
- These are susceptible to corrosion by sulphuric acid.

PLAIN CEMENT CONCRETE OR REINFORCED CEMENT CONCRETE

Advantages :

- Strong in tension as well as compression.
- Resistant to erosion and abrasion.
- Easily moulded, and can be in situ or precast pipes.
- Economical for medium and large sizes.
- These pipes are available in wide range of size and the trench can be opened and backfilled rapidly during maintenance of sewers.

Disadvantages :

- These pipes can get corroded and pitted by the action of H_2SO_4.
- The carrying capacity of the pipe reduces with time because of corrosion.
- The pipes are susceptible to erosion by sewage containing silt and grit.

BRICK SEWERS

- This material is used for construction of large size combined sewer or particularly for storm water drains.
- The pipes are plastered from outside to avoid entry of tree roots and groundwater through brick joints.
- These are lined from inside with stone ware or ceramic block to make them smooth and hydraulically efficient.
- Lining also makes the pipe resistant to corrosion.

CAST IRON SEWERS

- These pipes are stronger and capable to withstand greater tensile, compressive, as well as bending stresses.
- However, these are costly. cast iron pipes are used for outfall sewers, rising mains of pumping stations, and inverted siphons, where pipes are running under pressure.
- These are also suitable for sewers under heavy traffic load, such as sewers below railways and highways.
- They form 100% leak proof sewer line to avoid groundwater contamination.
- They are less resistant to corrosion; hence, generally lined from inside with cement concrete, coal tar paint, epoxy, etc.

STEEL PIPES

- Steel Pipes can withstand internal pressure, impact load and vibrations much better than CI pipes.
- They are more ductile and can withstand water hammer pressure better.
- These pipes cannot withstand high external load and these pipes may collapse when negative
- Pressure is developed in pipes.
- They are susceptible to corrosion and are not generally used for partially flowing sewers

DUCTILE IRON PIPES

- Ductile iron pipes can also be used for conveying the sewers.
- They demonstrate higher capacity to withstand water hammer.
- Internally these pipes are coated with cement mortar lining or any other polyethylene or poly wrap or plastic bagging/ sleeve lining to inhibit corrosion from the wastewater being conveyed, and various types of external coating are used to inhibit corrosion from the environment.
- Ductile iron has proven to be a better pipe material than cast iron but they are costly.
- Ductile iron is still believed to be stronger and more fracture resistant material.
- However, like most ferrous materials it is susceptible to corrosion.

PLASTIC SEWERS (PVC PIPES)

- Plastic is recent material used for sewer pipes. These are used for internal drainage works in house..
- They offer smooth internal surface.
- The additional advantages they offer are resistant to corrosion, light weight of pipe, economical in laying, jointing and maintenance, the pipe is tough and rigid, and ease in fabrication and transport of these pipes.

HIGH DENSITY POLYTHYLENE (HDPE) PIPES

- Use of HDPE pipes for sewers is recent development.
- They are not brittle like AC pipes and other pipes and hence hard fall during loading, unloading and handling do not cause any damage to the pipes.
- These are commonly used for conveyance of industrial wastewater. They offer all the advantages offered by PVC pipes.
- PVC pipes offer very little flexibility and normally considered rigid; whereas, HDPE pipes are flexible hence best suited for laying in hilly and uneven terrain. Flexibility allows simple handling and installation of HDPE pipes.
- Because of low density, these pipes are very light in weight.
- Due to light in weight, they are easy for handling, this reduces transportation and installation cost.
- HDPE pipes are non corrosive and offer very smooth inside surface due to which pressure losses are minimal and also this material resist scale formation.

GLASS FIBER REINFORCED PLASTIC PIPES

- This martial is widely used where corrosion resistant pipes are required.
- Glass fiber reinforced plastic (GRP) can be used as a lining material for conventional pipes to protect from internal or external corrosion.
- It is made from the composite matrix of glass fiber, polyester resin and fillers.
- These pipes have better strength, durability, high tensile strength, low density and high corrosion resistance.
- Glass reinforced plastic pipes represent the ideal solution for transport of any kind of water, chemicals, effluent and sewage, because they combine the advantages of corrosion resistance with a mechanical strength which can be compared with the steel pipes.

Typical properties that result in advantages in GRP pipes application can be summarized as follows:

- Light weight of pipes that allows for the use of light laying and transport means.
- Possibility of nesting of different diameters of pipe thus allowing additional saving in transport cost.
- Length of pipe is larger than other pipe materials.
- Easy installation procedures due to the kind of mechanical bell and spigot joint.
- Corrosion resistance material, hence no protections such as coating, painting or cathodic are athen necessary.
- Smoothness of the internal wall that minimizes the head loss and avoids the formation of deposits.
- High mechanical resistance due to the glass reinforcement.
- Absolute impermeability of pipes and joints both from external to internal and vice- versa.
- Very long life of the material.

CHAPTER-8

TYPES OF TREATMENT

TYPES OF TREATMENT

1) Preliminary Treatment
2) Primary Treatment
3) Secondary Treatment
4) Tertiary/advanced Treatment

➢ PRELIMINARY TREATMENT

- Preliminary systems are designed :
  - To remove or cut up the larger suspended and floating materials
  - To remove the heavy inorganic solids and excessive amounts of oil and grease.
- The purpose of preliminary treatment is
  - To protect pumping equipment and the subsequent treatment units.
- However, the quality of wastewater is not substantially improved by preliminary treatment.

Preliminary Treatment Includes:

- Screening:
- Grit Chamber:
- Oil and Grease Removal System

Screens :

- The primary treatment incorporates unit operations for removal of floating and suspended solids from the wastewater.
- They are also referred as the physical unit operations.
- The unit operations used are screening for removing floating papers, rages, cloths, plastics, cans stoppers, labels, etc.
- Grit chambers or detritus tanks for removing grit and sand, skimming tanks for removing oils and grease and primary settling tank for removal of residual settleable suspended matter.
- The screen can be of circular or rectangular opening. the screen composed of parallel bars or rods is called a rack.
- The screens are used to protect pumps, valves, pipelines, and other appurtenances from damage or clogging by rags and large objects.
- The cross section of the screen chamber is always greater (about 200 to 300 %) than the incoming sewer.
- The length of this channel should be sufficiently long to prevent eddies around the screen.
- The schematic diagram of the screen is shown in the figure.

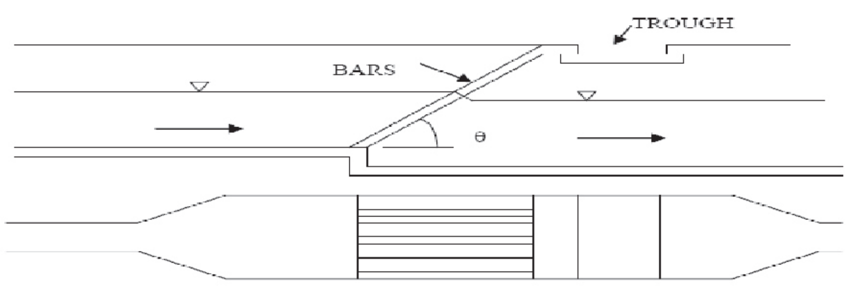


Fig.: 8.1

TYPES OF SCREENS

COARSE SCREEN

- It is used primarily as protective device and hence used as first treatment unit.
- Common type of these screens are bar racks (or bar screen), coarse woven-wire screens, and comminutors.
- Bar screens are used ahead of the pumps and grit removal facility. this screen can be manually cleaned or mechanically cleaned.
- Manually cleaned screens are used in small treatment plants.
- Clear spacing between the bars in these screens may be in the range of 15 mm to 40 mm.

FINE SCREENS

- fine screens are mechanically cleaned screens using perforated plates, woven wire cloths, or very closely spaced bars with clear openings of less than 20 mm, less than 6 mm typical.
- commonly these are available in the opening size ranging from 0.035 to 6 mm.
- fine screens are used for pretreatment of industrial wastewaters and are not suitable for sewage due to clogging problems, but can be used after coarse screening.
- fine screens are also used to remove solids from primary effluent to reduce clogging problem of trickling filters.
- various types of microscreens have been developed that are used to upgrade effluent quality from secondary treatment plant.
- fine screen can be fixed or static wedge-wire type, drum type, step type and centrifugal screens.

TYPES OF MEDIUM AND FINE SCREENS

INCLINED (FIXED)

- These are flat, cage, or disk type screens meant for removal of smaller particles.
- These are provided with opening of 0.25 to 2.5 mm.

DRUM SCREEN OR STRAINER

- It consists of rotating cylinder that has screen covering the circumferential area of the drum.
- The liquid enters the drum axially and moves radially out.
- Opening size of 1 to 5 mm and 0.25 to 2.5 mm is used for primary treatment and opening size of 6 to 40 µm is used for polishing treatment of secondary effluents.

QUANTITIES OF SCREENING

- The quantity of screening varies depending on the type of rack or screen used as well as sewer system (combined or separate) and geographic location.
- Quantity of screening removed by bar screen is 0.0035 to 0.0375 m^3/ 1000 m^3 of wastewater treated (typical value = 0.015 m^3/1000 m^3 of wastewater) in combined system.
- The quantity of screening increases during storm and can be as high as 0.225 m^3/1000 m^3 of wastewater

GRIT CHAMBER

- Grit chamber is the second unit operation used in primary treatment of wastewater and it is intended to remove suspended inorganic particles such as sandy and gritty matter from the wastewater.
- This is usually limited to municipal wastewater and generally not required for industrial effluent treatment plant, except some industrial wastewaters which may have grit.
- The grit chamber is used to remove grit, consisting of sand, gravel, cinder, or other heavy solids materials that have specific gravity much higher than those of the organic solids in wastewater.
- Grit can be disposed off after washing, to remove higher size organic matter settled along with grit particles; whereas, the suspended solids settled in primary sedimentation tank, being organic matter, requires further treatment before disposal.

HORIZONTAL VELOCITY IN FLOW THOUGH GRIT CHAMBER

- To prevent scouring of already deposited particles the magnitude of 'v' should not exceed critical horizontal velocity vc
- The grit chambers are designed to remove the smallest particle of size 0.2 mm with specific gravity around 2.65.
- For these particles, using above expression the critical velocity comes out to be vc = 0.228 m/sec.

SETTLING VELOCITY OF THE PARTICLES

- Settling velocity of any discrete particle depends on its individual characteristics and also on the characteristics of the fluid.

HORIZONTAL FLOW RECTANGULAR GRIT CHAMBER

- A free board of minimum 0.3 m and grit space of about 0.25 m is provided. for large sewage treatment plant, two or more number of grit chambers are generally provided in parallel.
- The detention time of 30 to 60 seconds is recommended for the grit chamber.

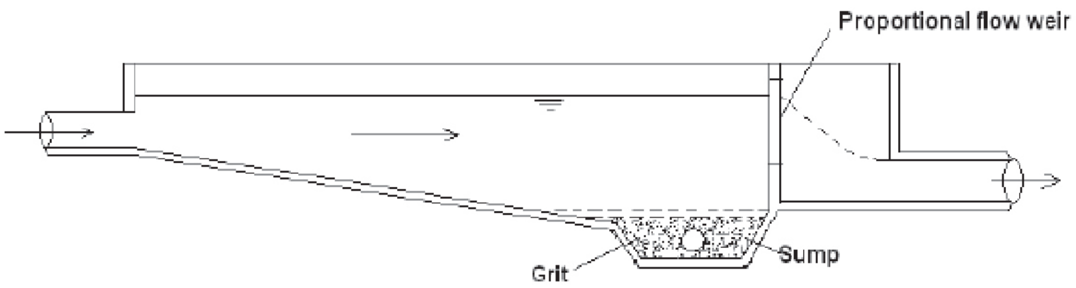


Fig.: 8.2

DISPOSAL OF GRIT

- considerable quantities of grit will be collected at the sewage treatment plant, about 0.004 to 0.2 m^3/ml.
- Quantity of grit will be more particularly for combined system.
- The grit collected can be disposed in the following manner:
- In large treatment plant, grit is incinerated with sludge
- In the past, grits along with screening was dumped into sea.
- Generally, grit should be washed before disposal to remove organic matter.
- Land disposal after washing is most common

SQUARE GRIT CHAMBER

- The horizontal flow rectangular grit chamber faces the problem of sedimentation of organic matter along with grit particles, requiring external washing of the grit before disposal.
- This problem can be minimized by providing square shape of the grit chamber rather than long rectangular channel.
- Minimum two number of grit chambers should be used to facilitate maintenance of the raking mechanism, whenever required.
- The grit deposited at the bottom is raked by rotating mechanism to a sump at the side of the tank, from which it is moved up by an inclined reciprocating rake or screw pump mechanism

AERATED GRIT CHAMBER

- Excessive wear of grit handling equipment and necessity of separate grit washer can be eliminated by using aerated grit chamber.
- It is designed for typical detention time of 3 minutes at maximum flow
- The air flow rate can be easily adjusted to control efficiency and 100% removal of grit can be achieved.
- Wastewater moves in the tank in helical path and makes two or three passes across the bottom of the tank at maximum flow (and more at less flow).
- Wastewater is introduced in the direction of roll in the grit chamber.
- The expansion in volume due to introduction of air must be considered in design.
- The aerated grit chambers are equipped with grit removal grab buckets, traveling on monorails over the grit collection and storage trough.
- Chain and bucket conveyers can also be used. two grit chambers in parallel are used to facilitate maintenance.
- Typical design details for aerated grit chamber are provided below (metcalf and eddy, 2003):
- Depth : 2 to 5 m
- Length : 7.5 to 20 m
- Width : 2.5 to 7.0 m
- Width to depth ratio: 1:1 to 5:1
- Detention time at peak flow: 2 to 5 min (3 minutes typical)
- Air supply m3/min.m of length : 0.15 to 0.45 (0.3 typical)

➢ PRIMARY TREATMENT

- The primary treatment is designed :
  - To remove the fine suspended organic matter.
  - It reduces 60-70 % of fine settleable suspended solids, which include 30-32 % organic suspended solids.
  - The primary treatment does not remove the colloidal & soluble organic content of the waste water.
- Primary treatment includes:
  - coagulation and flocculation unit following by primary sedimentation tank for the removal of inorganic & organic fine suspended solids.

PRIMARY SEDIMENTATION TANK

- After grit removal in grit chamber, the wastewater containing mainly lightweight organic matter is settled in the primary sedimentation tank (pst).
- The primary sedimentation tank generally removes 30 to 40% of the total bod and 50 to 70% of suspended solids from the raw sewage.
- The flow through velocity of 1 cm/sec at average flow is used for design with detention period in the range of 90 to 150 minutes.
- This horizontal velocity will be generally effective for removal of organic suspended solids of size above 0.1 mm.
- The efficiency of the sedimentation tank, with respect to suspended solids and bod removal, is affected by the following:
- Eddy currents formed by the inertia of incoming fluid, wind induced turbulence created at the water surface of the uncovered tanks
- Thermal convection currents
- Cold or warm water causing the formation of density currents that moves along the bottom of the basin, and thermal stratification in hot climates.

RECOMMENDATION FOR DESIGN OF PRIMARY SEDIMENTATION TANK

- Primary sedimentation tanks can be circular or rectangular tanks
- Designed using average dry weather flow and checked for peak flow condition.
- The numbers of tanks are determined by limitation of tank size.
- Two tanks in parallel are normally used to facilitate maintenance of any tank.
- The depth of mechanically cleaned tank should be as shallow as possible, with minimum 2.15 m.
- The average depth of the tank used in practice is about 3.5 m. in addition, 0.25 m for sludge zone and 0.3 to 0.5 m free board is provided.
- The floor of the tank is provided with slope 6 to 16 % (8 to 12 % typical) for circular tank and 2 to 8% for rectangular tanks.
- The scrappers are attached to rotating arms in case of circular tanks and to endless chain in case of rectangular tanks.
- These scrappers collect the solids in a central sump and the solids are withdrawn regularly in circular tanks.
- In rectangular tanks, the solids are collected in the sludge hoppers at the influent end, and are with drawn at fixed time intervals.

- The scrapper velocity of 0.6 to 1.2 m/min (0.9 m/min typical) is used in rectangular tank and flight speed of 0.02 to 0.05 rpm (0.03 typical) is used in circular tank
- The surface overflow rate of 40 $m^3/m^2.d$ (in the range 35 to 50 $m^3/m^2.d$) is used for design at average flow.
- At peak flow the surface overflow rate of 80 to 120 $m^3/m^2.d$ could be used when this PST is followed by secondary treatment
- The weir loading rate less than 185 $m^3/m.d$ is used for designing effluent weir length (in the range 125 to 500 $m^3/m.d$).
- Weir loading rate up to 300 $m^3/m.d$ is acceptable under peak flow condition
- The detention time in PST could be as low as 1 h to maximum of 2.5 h.
- Providing detention time of 1.5 to 2.5 h at average flow is a common practice.

OTHER PRIMARY TREATMENT SYSTEMS

- Other pre-treatment operation such as equalization, skimming tanks, flocculation and pre aeration are used sometimes.

EQUALIZATION

- Flow equalization is provided for dampening of flow rate variations so that a constant or nearly constant flow rate is achieved.
- The equalization can also be provided for dampening the fluctuation in pollutant concentration in the incoming wastewater to avoid shock loading on the treatment system
- To provide continuous feeding to the treatment system when the wastewater generation is intermittent
- To control ph fluctuations
- To control toxic concentration in the feed of the biological reactor.

EQUALIZATION CAN BE OF TWO TYPES

a) **Inline :** where all flow passes through equalization basin
b) **Off-line :** in this, the flow above average daily flow is diverted to equalization basin.
the pumping is minimized in this case but amount of pollutant concentration damping is considerably reduced.

- Location of equalization: location of equalization basin after primary treatment and before biological treatment is appropriate.
- This arrangement considerably reduces problem of sludge and scum in the equalization basin.
- If the equalization basin is placed before primary treatment, it must be provided with sufficient mixing to prevent solids deposition and concentration variations, and aeration to prevent odour problem.
- Most commonly submerged or surface aerators with power level of approximately 0.003 to 0.004 kw/m^3 are used. in diffused air mixing, air requirement of 3.74 m^3/m^3 (air flow rate to water flow rate) is used

VOLUME REQUIREMENT

- The volume required for the equalization tank can be worked out using an inflow mass diagram in which cumulative inflow volume is plotted versus the time of day.

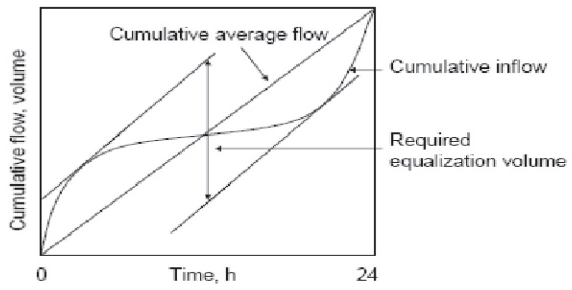


Fig.: 8.3

- In practice, the volume of tank is kept 10 to 20% greater than the theoretical volume. this additional volume is provided for the following:
- Not to allow complete drawdown to operate continuous mixing or aeration (e.g. floating aerators)
- Some volume must be provided to accommodate concentrated stream to get diluted wastewater.
- Safety for unforeseen changes in flow

SKIMMING TANKS

- It is a chamber so arranged that floating matter rises and remains on the surface of wastewater until removed
- While liquid flows out continuously through deep outlets or under partition or deep scum board.
- This may be accomplished in separate tank or combined with primary sedimentation.
- Skimming tanks are used to remove lighter, floating substances, including oil, grease, soap, pieces of cork and wood, vegetable debris, and fruit skins.

FLOCCULATION

- Flocculation is not commonly used for sewage treatment
- However, it may be required in treatment of industrial wastewater where organic matter is present in high concentration in colloidal form.
- Presence of such solids will increase the oxygen demand in aerobic wastewater treatment system, and may disturb the performance of anaerobic reactor like UASB reactor
- Due to presence of finely divided suspended solids which may not settle well in the reactor to undergo digestion.
- If flocculation is used, it is provided before the primary sedimentation tank.
- Flocculation is provided with the objective to form flocs from the finely divided matter.
- Mixing can be mechanical or air agitation type without any chemical addition.
- Provision of flocculation can increase removal of SS and BOD in primary sedimentation tank and help in increasing efficiency of secondary sedimentation tank after biological treatment.
- Detention time of 20 to 60 min (typical 30 min) is used in design of the flocculator.
- In case of mechanical mixing, maximum speed at periphery for the paddles induced flocculation with adjustable speed is 0.4 – 1.0 m/sec (typical 0.6 m/sec).
- For air agitation flocculation with tube diffusers, air supply is generally in the range of 0.6 – 1.2 m^3/ ml.

➢ SECONDARY TREATMENT

- Secondary treatment is commonly referred to as the biological process.
- Secondary treatment is used to remove the soluble and colloidal organic matter which remains after primary treatment.
- This matter should be removed before discharging to receiving waters, to avoid interfering with subsequent downstream users.

SECONDARY TREATMENT INCLUDES :

- Aeration tank/biological treatment unit
- Secondary settling tank
- Secondary treatment of the wastewater could be achieved by chemical unit processes such as chemical oxidation, coagulation-flocculation and sedimentation, chemical precipitation, etc.
- Or by employing biological processes (aerobic or anaerobic) where bacteria are used as a catalyst for removal of pollutant.
- For removal of organic matter from the wastewater, biological treatment processes are commonly used all over the world.
- Hence, for the treatment of wastewater like sewage and many of the agro-based industries and food processing industrial wastewaters
- The secondary treatment will invariably consist of a biological reactor either in single stage or in multi stage as per the requirements to meet the discharge norms.

BIOLOGICAL TREATMENT

- The objective of the biological treatment of wastewater is to remove organic matter from the wastewater which is present in soluble and colloidal form or to remove nutrients such as nitrogen and phosphorous from the wastewater.
- The microorganisms (principally bacteria) are used to convert the colloidal and dissolved carbonaceous organic matter into various gases and into cell tissue.
- Biological removal of degradable organics involves a sequence of steps including mass transfer, adsorption, absorption and biochemical enzymatic reactions.
- Stabilization of organic substances by microorganisms in a natural aquatic environment or in a controlled environment of biological treatment systems is accomplished by two distinct metabolic processes:
- Respiration and synthesis, also called as catabolism and anabolism, respectively.
- **Respiration:** a portion of the available organic or inorganic substrate is oxidized by the biochemical reactions, being catalyzed by large protein molecules known as enzymes produced by microorganism to liberaze energy.
- Under aerobic conditions, the oxygen acts as the final electron acceptor for the oxidation.
- Under anaerobic conditions sulphates, nitrates, nitrites, carbon dioxide and organic compounds acts as an electron acceptor. metabolic end products of the respiration are true inorganics like CO_2, water, ammonia, and H_2S
- The energy derived from the respiration is utilized by the microorganisms to synthesize new protoplasm through another set of enzyme catalyzed reactions, from the remaining portion of the substrate.
- The energy is also required by the microorganisms for maintenance of their life activities.
- In the absence of any suitable external substrate, the microorganisms derive this energy through the oxidation of their own protoplasm. such a process is known as endogenous respiration (or decay)

- The metabolic end products of the endogenous respiration are same as that in primary respiration.
- The metabolic processes in both aerobic and anaerobic processes are almost similar
- The yield of energy in an aerobic process, using oxygen as electron acceptor, is much higher than in anaerobic condition.
- This is the reason why the aerobic systems liberates more energy and thus produce more new cells than the anaerobic systems.

PRINCIPLES OF BIOLOGICAL WASTEWATER TREATMENT

- The end products of the metabolisms are either gas or liquid; and on the other hand the synthesized biological mass can flocculate easily and it can be easily separated out in clarifiers.
- Therefore, the biological treatment system usually consists of
- (1) a biological reactor
- (2) a sedimentation tank, to remove the produced biomass called as sludge.

CATABOLISM AND ANABOLISM :

- The most important mechanism for the removal of organic material in biological wastewater treatment system is by bacterial metabolism.
- metabolism refers to the utilization of the organic material, either as a source of energy or as a source for the synthesis of cellular matter.
- When organic material is used as an energy source, it is transferred into stable end products, a process known as catabolism.
- In the process of anabolism the organic material is transformed and incorporated into cell mass.
- Anabolism is an energy consuming process and it is only possible if catabolism occurs at the same time to supply the energy needed for the synthesis of the cellular matter.
- Thus, the processes of catabolism and anabolism are interdependent and occur simultaneously.

NUTRITIONAL REQUIREMENTS FOR MICROBIAL GROWTH

- For reproduction and proper functioning of an organism it must have a source of energy
- Carbon for the synthesis of new cellular material
- Nutrients such as N, P, K, S, Fe, Ca, Mg, etc.
- Energy needed for the cell synthesis may be supplied by light or by chemical oxidation reaction catalyzed by the bacteria.
- Accordingly the microbes can be classified as:
- **Phototrophs :** organisms those are able to use light as an energy source.
- These may be heterotrophic (certain sulphur reducing bacteria) or autotrophic (photosynthetic bacteria and algae).
- **Chemotrophs :** organisms that derive their energy from chemical reaction. these may be either heterotrophic, those derive energy from organic matter like protozoa, fungi, and most bacteria or may be autotrophic like nitrifying bacteria.
- Accordingly they are called as chemoheterotrophs
- **Source of carbon:** the source of carbon for synthesis of new cell could be organic matter (used by heterotrophs) or carbon dioxide (used by autotrophs).

- **Nutrient and growth factor requirement :** the principal inorganic nutrients required by microorganisms are N, S, P, K, Mg, Ca, Fe, Na, Cl, etc. some of the nutrients are required in trace amount (very small amount) such as Zn, Mn, Mo, Se, Co, Ni, Cu, etc. in addition to inorganic nutrients, organic nutrients may also be required by some organisms and they are known as 'growth factors'.

TYPES OF MICROBIAL METABOLISM

- **Aerobic microorganisms:** when molecular oxygen is used as terminal electron acceptor in respiratory metabolism it is referred as aerobic respiration.
- The organisms that exist only when there is molecular oxygen supply are called as obligately aerobic.
- **Anoxic microorganisms:** for some respiratory microorganisms oxidized inorganic compounds such as sulphate, nitrate and nitrite can function as electron acceptors in absence of molecular oxygen; these are called as anoxic microorganisms.
- **Obligately anaerobic:** these are the microorganisms those generate energy by fermentation and can exist in absence of oxygen.

TYPES OF SECONDARY TREATMENT

Various types of processes used in secondary treatment are:

- Aerobic treatment :
    - ASP
    - Extended aeration
    - Submerged aerobic fixed film reactor
    - Moving bed bioreactor
    - Membrane bioreactor
- Anaerobic treatment :
    - Up flow anaerobic sludge blanket reactor
    - Anaerobic migrating blanket reactor

➢ TERTIARY TREATMENT

INTRODUCTION

- Secondary treatment removes 85 to 95 percent of bod and tss and minor portions of nitrogen, phosphorus, and heavy metals.
- Tertiary treatment is the next wastewater treatment process after secondary treatment.
- This treatment is sometimes called as the final or advanced treatment and consists of removing the organic load left after secondary treatment for removal of nutrients from sewage and particularly to kill the pathogenic bacteria.
- The effluents from secondary sewage treatment plants contain both nitrogen (N) and phosphorus (P).
- N and P are ingredients in all fertilizers.
- When excess amounts of N and P are discharged, plant growth in the receiving waters may be accelerated which results in eutrophication in the water body receiving such waste.
- The purpose of tertiary treatment is to provide a final treatment stage to raise the effluent quality before it is discharged to the receiving environment such as sea, river, lake, ground, etc., or to raise the treated water quality to such a level to make it suitable for intended reuse.

- This step removes different types of pollutants such as organic matter, ss, nutrients, pathogens, and heavy metals that secondary treatment is not able to remove.
- Wastewater effluent becomes even cleaner in this treatment process through the use of stronger and more advanced treatment systems.
- Tertiary treatment is costly as compared to primary and secondary treatment methods.

NEED OF TERTIARY TREATMENT

- Tertiary treatment may be provided to the secondary effluent for one or more of the following contaminant further.
- To remove total suspended solids and organic matter those are present in effluents after secondary treatment.
- To remove specific organic and inorganic constituents from industrial effluent to make it suitable for reuse.
- To make treated wastewater suitable for land application purpose or directly discharge it in to the water bodies like rivers, lakes, etc.
- To remove residual nutrients beyond what can be accomplished by earlier treatment methods.
- To remove pathogens from the secondary treated effluents.
- To reduce total dissolved solids (TDS) from the secondary treated effluent to meet reuse quality standards.

TERTIARY TREATMENTS

- In advanced wastewater treatment, treatment options or methods are dependent upon the characteristics of effluent to be obtained after secondary treatment to satisfy further use or disposal of treated wastewater.

CHAPTER-9

Aerobic Wastewater Treatment Processes

1) ACTIVATED SLUDGE PROCESS

- Conventional biological treatment of wastewater under aerobic conditions includes activated sludge process (ASP).
- The activated sludge process consists of an aeration tank, where organic matter is stabilized by the action of bacteria under aeration and a secondary sedimentation tank (SST),
- Where the biological cell mass is separated from the effluent of aeration tank and the settle sludge is recycled partly to the aeration tank and remaining is wasted recycling is necessary for activated sludge process.
- The aeration conditions are achieved by the use of diffused or mechanical aeration.
- Diffusers are provided at the tank bottom, and mechanical aerators are provided at the surface of water, either floating or on fixed support.

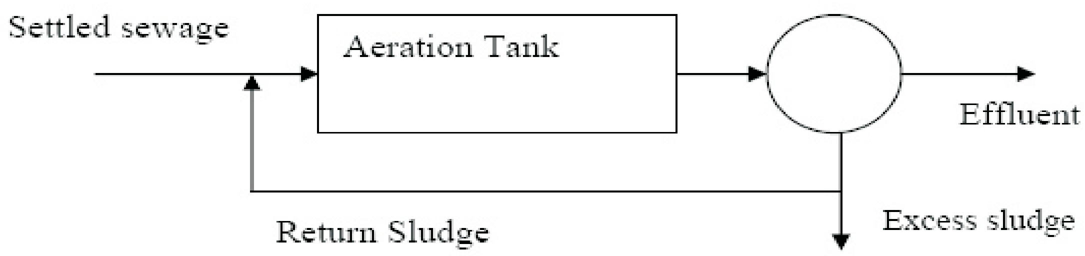


Figure 19.1 Conventional Activated Sludge Process

Fig.: 9.1

- **Loading rate:** the organic matter loading rate applied to the reactor is quantified as kg of bod applied per unit volume of the reactor per day, called as volumetric loading rate, or kg of bod applied per day per unit mass of microorganisms present in the reactor
- (I.E. in the aeration tank), called as organic loading rate or f/m. this can be calculated as stated below:
- Volumetric loading = Q x BOD x 10^{-3} / vol
- Where, bod = influent BOD_5 to aeration tank, mg/l
- Q = flow rate, m^3/day
- Vol. = volume of aeration tank, m^3
- Organic loading rate, F/M = Q x BOD / (V x XT)
- Where, XT = MLVSS concentration in the aeration tank, mg/l
- The F/M ratio is the main factor controlling bod removal.
- Lower F/M values will give higher bod removal. The F/M can be varied by varying mlvss concentration in the aeration tank.

SOLID RETENTION TIME (SRT) OR MEAN CELL RESIDENCE TIME (MCRT)

- The retention of the sludge depends on the settling rate of the sludge in
- The SST if sludge settles well in the SST proper recirculation of the sludge in aeration tank in possible
- This will help in maintaining desired SRT in the system. otherwise, if the sludge has poor settling properties, it will not settle in the SST and recirculation of the sludge will be difficult
- This may reduce the SRT in the system. the SRT can be estimated as stated below:
- SRT = Kg of MLVSS in aeration tank
- (kg of VSS wasted per day + kg of VSS lost in effluent per day)
- Generally, the VSS lost in the effluent are neglected as this is very small amount as compared to artificial wasting of sludge carried out from the sludge recycle line or from aeration tank

SLUDGE VOLUME INDEX

- The quantity of the return sludge is determined on volumetric basis.
- The sludge volume index (SVI) is the volume of the sludge in ml for one gram of dry weight of suspended solids (SS), measured after 30 minutes of settling.
- The SVI varies from 50 to 150 ml/ g of SS. lower SVI indicates better settling of sludge.

QUANTITY OF RETURN SLUDGE

- Usually solid concentration of about 1500 to 3000 mg/l (MLVSS 80% of mlss) is maintained for conventional ASP and 3000 to 6000 mg/l for completely mixed ASP.
- Accordingly the quantity of return sludge is determined to maintain this concentration.
- The sludge return ratio is usually 20 to 50%.
- The F/M ratio is kept as 0.2 to 0.4 for conventional ASP and 0.2 to 0.6 for completely mixed ASP.

AERATION IN ASP

- Aeration units can be classified as:
  1) diffused air units
  2) mechanical aeration units
  3) combined mechanical and diffused air units.

TYPES OF ACTIVATED SLUDGE PROCESS

- Conventional aeration
- In conventional asp the flow model in aeration tank is plug flow type.
- Both the influent wastewater and recycled sludge enter at the head of the tank and are aerated for about 5 to 6 hours for sewage treatment the influent and recycled sludge are mixed by the action of the diffusers or mechanical aerators.
- Rate of aeration is constant throughout the length of the tank.
- During the aeration period the adsorption, flocculation and oxidation of organic matter takes place.

- The F/M ratio of 0.2 to 0.4 kg BOD/kg VSS.d and volumetric loading rate of 0.3 to 0.6 kg BOD/m^3.d is used for designing this type of ASP.
- Lower mixed liquor suspended solids (MLSS) concentration is maintained in the aeration tank of the order of 1500 to 3000 mg/l and mean cell residence time of 5 to 15 days is maintained.
- The hydraulic retention time (HRT) of 4 to 8 h is required for sewage treatment.
- higher Hrt may be required for treatment of industrial wastewater having higher BOD concentration.
- The sludge recirculation ratio is generally in the range of 0.25 to 0.5

TAPERED AERATION

- By tapered aeration the efficiency of the aeration unit will be increased and it will also result in overall economy.
- The F/M ratio and volumetric loading rate of 0.2 to 0.4 kg BOD/kg VSS.d and 0.3 to 0.6 kg BOD/m^3.d, respectively, are adopted in design.
- Other design recommendation are mean cell residence time of 5 to 15 days, MLSS of 1500 to 3000 mg/l, HRT of 4 to 8 h and sludge recirculation ratio of 0.25 to 0.5.

2) EXTENDED AERATION SYSTEM

- Extended aeration is a type of activated sludge process with no primary settling and very long aerobic detention time to generate less excess sludge overall.
- It is ideal for smaller flow, modular applications that require low maintenance such as residential subdivisions.
- But the long HRT of extended aeration requires larger basins.
- In extended aeration process, low organic loading rate (F/M) and long aeration time is used to
- Operate the process at endogenous respiration phase of the growth curve.
- Since, the cells undergo endogenous respiration, the excess sludge generated in this process is low and the sludge can directly be applied on the sand drying beds where aerobic digestion and dewatering of the sludge occurs.
- The primary sedimentation can be eliminated when extended aeration process is used to simplify the operation of sludge handling.
- This type of activated sludge process is suitable for small capacity plant, such as package sewage treatment plant or industrial wastewater treatment plant of small capacity of less than 3000 m^3/day.
- The aeration tank in this case is generally completely mixed type.
- Lower F/M ratio of 0.05 to 0.15 kg BOD/kg VSS.d and volumetric loading of 0.1 to 0.4 kg BOD/m^3.d is used for designing extended aeration ASP.
- Mixed liquor suspended solids (MLSS) concentration of the order of 3000 to 6000 mg/l and mean cell residence time of 20 to 30 days is maintained.
- Higher mean cell residence time is necessary to maintain endogenous growth phase of microorganisms.
- The hydraulic retention time (HRT) of 18 to 36 h is required the sludge recirculation ratio is generally in the range of 0.75 to 1.5.

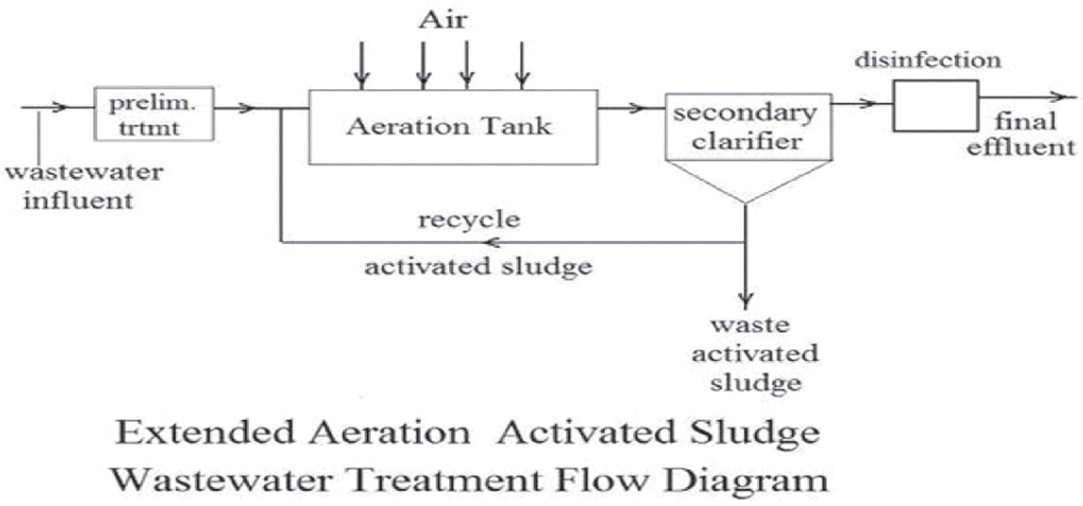


Fig.: 9.2

APPLICATIONS

- Municipal and domestic sewage treatment
- Industrial wastewater effulents including
- Breweries
- Chemical processing
- Dairies
- Distilleries
- Pharmaceuticals
- Food processing
- Textiles etc...

DESIGN CRITERIA

- Raw effluent data such as BOD, COD, TSS, TDS, Oil & Grease
- FM ratio
- MLSS conc.
- Detention time
- Final treated effluent quality data

3) SEQUENCING BATCH REACTOR (SBR)

- A sequencing batch reactor (SBR) is used in small package plants and also for centralized treatment of sewage.
- The SBR system consists of a single completely mixed reactor in which all the steps of the activated sludge process occurs .
- The reactor basin is filled within a short duration and then aerated for a certain period of time.
- After the aeration cycle is complete, the cells are allowed to settle for a duration of 0.5 h and effluent is decanted from the top of the unit which takes about 0.5 h.
- Decanting of supernatant is carried out by either fixed or floating decanter mechanism
- When the decanting cycle is complete, the reactor is again filled with raw sewage and the process is repeated.
- An idle step occurs between the decant and the fill phases.
- The time of idle step varies based on the influent flow rate and the operating strategy.
- During this phase, a small amount of activated sludge is wasted from the bottom of the SBR basin.
- A large equalization basin is required in this process, since the influent flow must be contained while the reactor is in the aerating cycle.
- This process is popular because entire process uses one reactor basin.
- In areas where there is a limited amount of space, treatment takes place in a single basin instead of multiple basins, allowing for a smaller footprint.
- In the effluent low total-suspended-solid values of less than 10 mg/l can be achieved consistently through the use of effective decanters that eliminate the need for a separate clarifier.
- The treatment cycle can be adjusted to undergo aerobic, anaerobic and anoxic conditions in order to achieve biological nutrient removal, including nitrification, denitrification and some phosphorus removal.
- The food to microorganism (F/M) ratio is one of the significant design and operational parameters of activated sludge systems.
- A balance between substrate consumption and biomass generation helps in achieving system equilibrium.
- The F/M ratio is responsible for the decomposition of organic matter.
- The type of activated sludge system can be defined by its F/M ratio as below:
- Extended aeration, $0.05 < F/M < 0.15$
- Conventional activated sludge system, $0.2 < F/M < 0.4$
- Completely mixed, $0.2 < F/M < 0.6$
- High rate, $0.4 < F/M < 1.5$

$$F/M = \frac{[\text{BOD of wastewater } (\text{g/m}^3)]\ [\text{Influent flow rate } (\text{m}^3/\text{d})]}{[\text{Reactor volume } (\text{m}^3)]\ [\text{Reactor biomass } (\text{g/m}^3)]}$$

$$F/M = \frac{S_0\, Q_0}{V\, X}$$

4) BIOLOGICAL NUTRIENT REMOVAL

- Biological nutrient removal (BNR) removes total nitrogen (TN) and total phosphorus (TP) from wastewater through the use of microorganisms under different environmental conditions in the treatment process
- Nitrogen and phosphorus are the primary causes of cultural eutrophication (i.e., nutrient enrichment due to human activities) in surface waters.
- Uptake into biological cell mass

Nitrogen removal is done in two stages:

- 1) Biological nitrification (conversion to nitrate)
- 2) Biological denitrification (conversion to n_2 gas)
- Nitrifiction conversion of ammonia to nitrite (nitrosomonas)
  $NH_4^+ + 2\ O_2 \rightarrow NO_2^- + 2\ H^+ + H_2O$

Biological nitrification

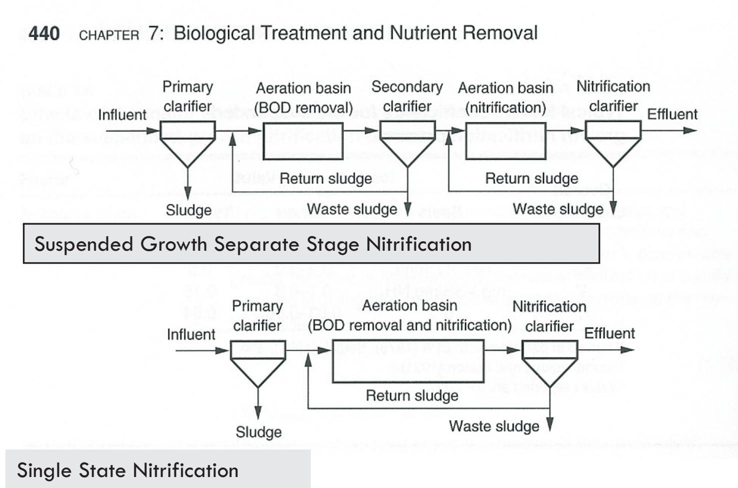
Conversion of nitrite to nitrate (nitrobacter)

$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$

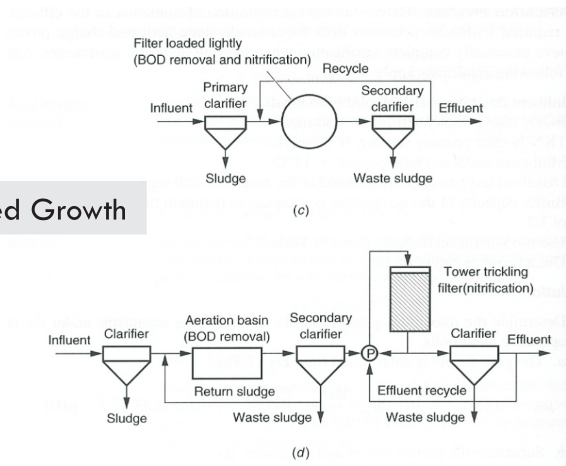
- for each mg of NH_4^+ converted…
- 3.96 mg of o_2 are utilized (need oxygen)
- 0.31 mg of new cells are formed
- 7.01 mg of alkalinity are removed

- Nitrifying bacteria are sensitive and susceptible to a variety of conditions.
- The following factors affect nitrification:
- Concentration of NH_4^+ and NO_2^-
- BOD/TKN ratio (bod should be gone/removed)
- Dissolved oxygen concentration (need oxygen)
- Temperature
- pH (7.5 to 8.6)

NITRIFICATION PROCESSES



Attached Growth



Attached Growth Nitrification following Act. Sludge

Fig.: 9.3

DENITRIFICATION

- Need low (no) oxygen (< 1 mg/l)
- Need carbon source (bod in wastewater)
- Neutral ph (ph 7)
- Concentiation of nitrate
- Separate denitrification reactor or
- combined carbon oxidation-nitrification-denitrification reactor
- A series of alternating aerobic and anoxic stages
- Reduces the amount of air needed
- No need for supplemental carbon source

BIOLOGICAL DENITRIFICATION

- A modification of aerobic pathways **(no oxygen)** same bacteria that consume carbon material aerobically
- denitrifying bacteria obtain energy from the conversion of NO_3^- to N_2 gas, but require a carbon source

  $NO_3^- + CH_3OH + H_2CO_3 \rightarrow C_5H_7O_2N + N_2 + H_2O + HCO_3^-$

COMBINED NITRIFICATION/DENITRIFICATION

(Note Alternating Regions Of Aerobic And Anoxic)

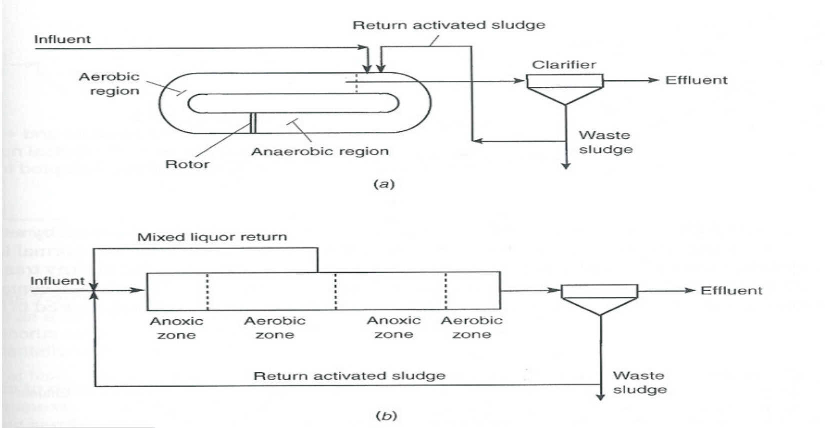


Fig.: 9.4
Combined single-stage nitrification-denitrification systems: (a) oxidation ditch and (b) four-stage plug-flow Bardenpho.

PHOSPHORUS REMOVAL

- Total effluent phosphorus comprises soluble and particulate phosphorus. particulate phosphorus can be removed from wastewater through following methods:-
- Chemical precipitation
- Calcium (lime) addition at high ph (>10)
- Reacts with alkalinity
- Alum (aluminum sulfate) precipitation
- Iron precipitation

5) MOVING BED BIOFILM REACTOR (MBBR)

- Moving bed biofilm reactor was developed by norwegian company, kaldnes miljoteknologies.
- This is mainly attached growth process where media is not stationary and it moves freely in the reactor to improve substrate removal kinetics.
- Small cylindrical shaped polyethylene carrier elements (sp. density 0.96 g/cm^3) are added in aerated or non-aerated basins to support biofilm growth.
- The biofilm carriers are retained in the reactor by the use of a perforated plate (5 x 25 mm slots) at the tank outlet.
- Thus, this media having larger size cannot escape the reactor along with the effluent.
- Air agitation or mixers are used to continuously circulate the packing and to keep it moving so as to establish optimum contact with substrate present in wastewater and bacteria attached to the media.
- Packing may fill 25 to 50% of tank volume, with specific surface area of about 200 to 500 m^2 /m^3 of bulk packing volume.
- this arrangement offers advantage that no return sludge is required and since the media is moving, there is no chance of blocking the media which may require back washing.

MOVING BED BIOREACTOR

- The moving bed bio reactor (MBBR) process utilize the attached bio-film and provides smaller footprint solution for with lower capital and operating costs.
- The suspended biomass carriers are designed to create a large surface area for biofilm growth.

Benefits include :

- an enhanced biological wastewater treatment process without increasing the plant footprint.
- MBBR process is ideally suited for retrofit/upgrade of existing installation with minimum changes in the existing setup.

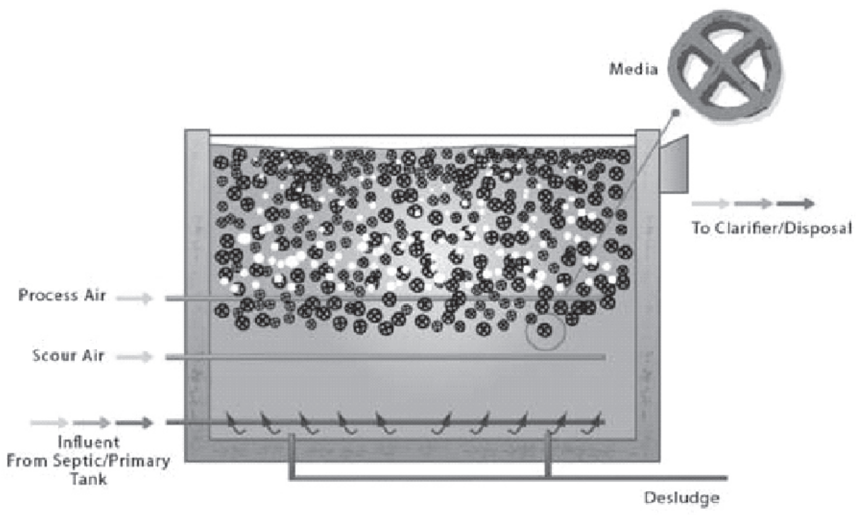


Fig.: 9.5

APPLICATION

- Municipal and domestic sewage treatment
- Industrial wastewater effluents including
- Breweries
- Chemical processing
- Dairies
- Distilleries
- Pharmaceuticals
- Food processing
- Textiles etc...

DESIGN CRITERIA

- Raw effluent data such as BOD, COD, TSS, TDS, Oil & Grease
- Organic loading rate
- Final treated effluent quality data

6) MEMBRANE BIOREACTOR

- Membrane bio reactor (MBR) technique, a new method for wastewater treatment, integrates membrane separation and biotechnology
- Rejects activated sludge and macromolecular organic Matter in aerobic tank/mbr tank with membrane separation plant, thus saving the use of secondary sedimentation tank.
- Consequently, the concentration of activated sludge rises greatly, the HRT and the SRT could be controlled separately, and difficult degraded matters are constantly degraded and reacting in reactor.
- Fig. shows the typical mbr concept of combination of activated sludge process and membrane filtration.

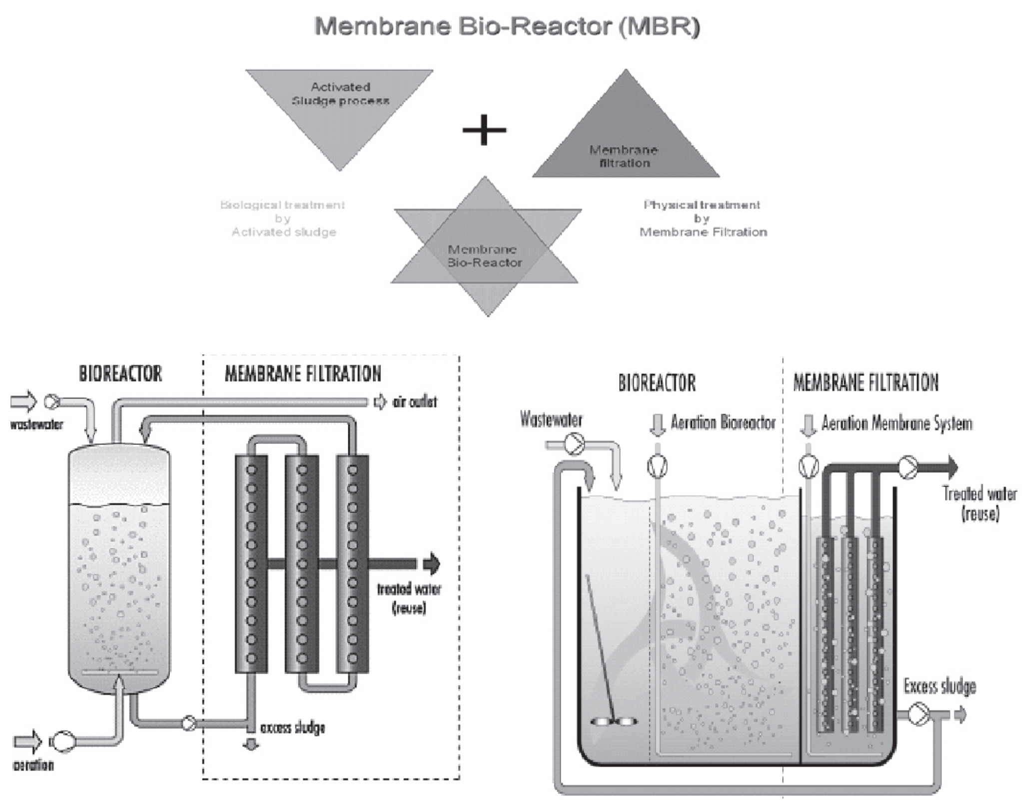


Fig.: 9.6

APPLICATION

- Need to upgrade old plant
- Need to preserve appearance of a clean/ tourist area(hospitals, hotels, malls)
- Housing complex
- Hotels & township
- Golf & country club
- Industrial estates
- Industrial waste treatment
- Waste recycle
- Existing plant upgrade/ capacity expansion
- Ro pretreatment of sea water and brackish waters
- Low area requirement

DESIGN CRITERIA

- Raw effluent data such as BOD, COD, TSS, TDS, Oil & Grease
- Organic loading rate
- Final treated effluent quality data

7) SUBMERGED AEROBIC FIXED FILM REACTOR

- Saff treatment is based on aerobic attached growth process and used in the secondary treatment of effluent/sewage treatment plant.
- The equipment consists of specially designed synthetic media, which facilitates attached fixed film growth of micro-organisms.
- The media is supported by channels.
- Diffusers are provided for efficient oxygen transfer.

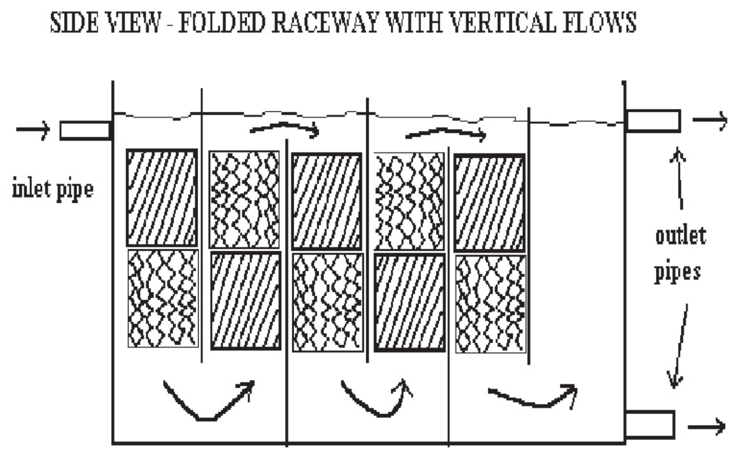


Fig.: 9.7

APPLICATION

- Municipal and domestic sewage treatment
- Industrial wastewater effluents including
- Breweries
- Chemical processing
- Dairies
- Distilleries
- Pharmaceuticals
- Food processing
- Abattoirs
- Textiles etc...

DESIGN CRITERIA

- Raw effluent data such as BOD, COD, TSS, TDS, Oil & Grease
- Volumetric loading
- Final treated effluent quality data

SECONDARY SEDIMENTATION

- The secondary sedimentation facility is provided after the biological reactor to facilitate the sedimentation of the cells produced during biological oxidation of organic matter.
- If these cells produced are not removed, complete treatment will not be achieved as these cells will represent about 30 to 60% of the organic matter present in untreated wastewater in aerobic treatment.
- Depending on the type of reactor used fraction of these settled cells is returned back to the reactor and remaining cells are wasted as excess sludge for further treatment.

CHAPTER-10

ANAEROBIC WASTEWATER TREATMENT PROCESSES

BACKGROUND

- Anaerobic biological treatment is well understood and used frequently as anaerobic digesters to treat complex organic solid wastes such as primary and secondary wastewater sludge.
- However, it has not been used much in the past to treat low strength organic wastewaters from industrial and domestic applications.
- Aerobic processes were preferred for treatment of these wastewater streams because they are easy to operate and can tolerate process fluctuations.
- In comparison, anaerobic reactors were assumed to be less stable under fluctuations, more expensive to install and require long start-up time.
- This belief was due to limited knowledge of the process and reactor
- Today the anaerobic treatment has emerged as a practical and economical alternative to aerobic treatment due to significant advantages over aerobic treatment

ANAEROBIC DEGRADATION OF ORGANIC MATTER

- The factors that determine the removal efficiency of biodegradable organic matter are:
- The nature and composition of the organic matter to be removed
- Suitability of environmental factors
- Sludge retention time in the reactor
- The intensity of mixing, hence contact between bacterial biomass and organic matter.
- Specific loading of organic matter with respect to bacterial sludge mass, and retention time. factors (1) and (2) are basically dependent on wastewater characteristics, whereas (3) to (5) are related to the type and design of the treatment system.

1) UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) REACTOR

- It is somewhat modified version of the contact process, based on an upward movement of the liquid waste through a dense blanket of anaerobic sludge.
- No inert medium is provided in these systems. the biomass growth takes place on the fine sludge particles, which then develop as sludge granules of high specific gravity.
- The reactor can be divided in three parts (figure 21.3), sludge bed, sludge blanket and three phase separator (gas-liquid-solid, gls separator) provided at the top of the reactor. the sludge bed consists of high concentration of active anaerobic bacteria (40 – 100 g/l) and it occupies about 40 to 60% of reactor volume.
- Majority of organic matter degradation (> 95%) takes place in this zone. the sludge consists of biologically formed granules or thick flocculent sludge.
- Treatment occurs as the wastewater comes in contact with the granules and/or thick flocculent sludge.
- The gases produced causes internal mixing in the reactor.some of the gas produced within the sludge bed gets attached to the biological granules.
- The free gas and the particles with the attached gas rise to the top of the reactor.
- On the top of sludge bed and below gls separator, thin concentration of sludge is maintained, which is called as sludge blanket.
- This zone occupies 15 to 25% of reactor volume
- Maintaining sludge blanket zone is important to dilute and further treat the wastewater stream that has bypassed the sludge bed portion following the rising biogas.
- The GLS separator occupies about 20 to 30% of the reactor volume. the particles that raise to the

liquid surface strike the bottom of the degassing baffles, which causes the attached gas bubbles to be released.

- The degassed granules typically drop back to the surface of the sludge bed.
- The free gas and gas released from the granules is captured in the gas collection domes located at the top of the reactor.
- Liquid containing some residual solids and biological granules passes into a settling chamber, where the residual solids are separated from the liquid.
- The separated solids fall back through the baffle system to the top of the sludge blanket.

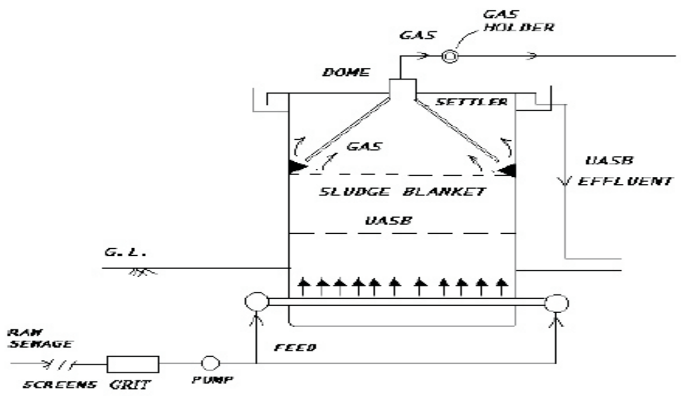


Fig.: 10.1 Upflow Anaerobic Sludge Blanket Reactor

- The granular biomass from the existing uasb reactor can be used as inoculum material to start-up new UASB reactor.
- When such material is not available, non-granular material such as anaerobic digested sludge, waste activated sludge and cow dung manure can be used as inoculum.
- Granular sludge can be developed using non-granular material for inoculation.
- organic loading in the range of 1-20 kg COD /m^3.d can be applied with removal efficiency of 75 to 85 % and HRT of 4 to 24 h.

POST TREATMENT

- The UASB reactor is an efficient process for removal of organic material and suspended
- Solids from sewage or industrial effluents.
- Particularly, this process is more attractive for treatment of sewage in warm climate.
- However, the UASB reactor can hardly remove macronutrients (nitrogen and phosphorous), and pathogenic microorganisms are only partially removed.
- Hence, depending on the final disposal of the effluent quality, post treatment may be required for removal of suspended solids, organic matter, nutrients, and pathogens present in the raw wastewaters.
- UASB reactor can hardly remove any nitrogen from the wastewater.
- Hence, effluent from uasb reactor is suitable for irrigation purposes. uasb reactor when followed by post treatment such as aeration and/or sedimentation could conveniently achieve irrigation standards.
- The aeration can be obtained to the effluent flowing through a channel to an irrigation area.

- Where, the treatment efficiency is adequate to meet the discharge standards, further treatment such as, aeration is only necessary to destroy anaerobicity.
- When stricter effluent standards have to be met (as for river discharge) some better form of post-treatment may become necessary.
- The use of aerobic biological treatment is generally preferred for this polishing treatment.
- The aerobic process such as, biotowers, conventional activated sludge process, or extended aeration can be employed as a second stage treatment.
- Where the effluent from uasb reactor is expected to be high in nutrient such as nitrogen and phosphorous,
- The post treatment need to be designed for removal of these nutrients to meet discharge standards for surface water.
- Shallow oxidation ponds can also be used after uasb reactor for complete treatment of wastewater.

UASB

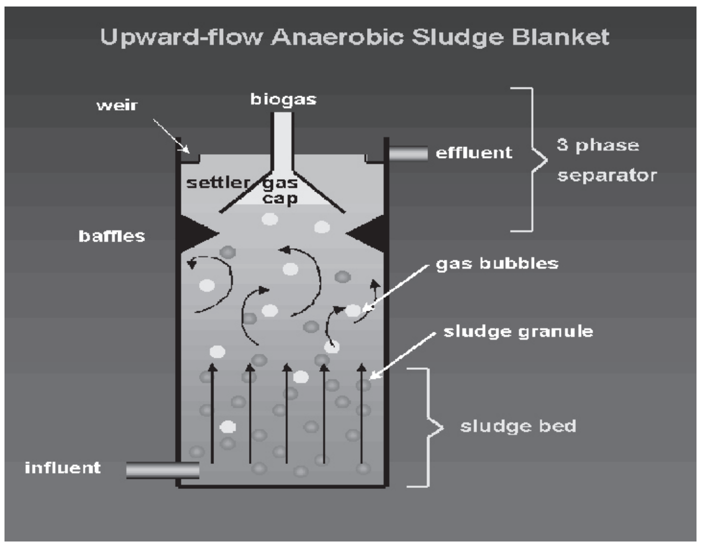


Fig.: 10.2

MERITS OF ANAEROBIC DECOMPOSITION PROCESS

it has been recognized that the anaerobic treatment is in many ways ideal for wastewater treatment and has several merits mentioned as below:

- A high degree of waste stabilization;
- A low production of excess biological sludge and this sludge can be directly dried on sludge drying bed without further treatment due to better dewatering ability;
- Low nutrient requirements, hence anaerobic treatment is attractive for the treatment of wastewater where external nutrient addition is required;
- No oxygen requirement, hence saving in power required for supply of oxygen in aerobic methods;

- Production of valuable byproduct, methane gas;
- Organic loading on the system is not limited to oxygen supply hence higher loading rate as compared to aerobic processes can be applied.
- Less land required as compared to many aerobic process.
- Non-feed conditions for few months do not affect adversely to the system and this makes it attractive option for seasonal industrial wastewater treatment.
- Quantity of biological solids produced in the anaerobic systems per unit weight of organic material is much less than that in aerobic systems.
- This is a major advantage of the anaerobic process as the quantity of sludge for ultimate disposal is reduced.
- This is a result of conversion of volatile solids present, to the high energy level end products such as methane, carbon dioxide and water.
- Methane has a definite economic value as a fuel, and it is used as a source of energy for both heat and power in many installations.

APPLICATION

- biological treatment of wastewater with low to very high strength of wastewater
- sewage treatment for medium to large towns/ cities.
- treatment of distillery spent wash / pulp mill black liquor.
- simple operation
- energy production

DESIGN CRITERIA

- Raw effluent data such as BOD, COD, TSS, TDS, Oil & Grease
- Organic loading rate

2) ANAEROBIC TREATMENT-AMBR

- The ambr is similar to the anaerobic baffled reactor (a series of unmixed compartments) with the added features of mechanical mixing in each stage
- An operating approach designed to hold the sludge in the system without resort to packing or settler for additional solids capture.
- In the ambr, the last stage is left unmixed to maximize settlin
- The feed and effluent points are alternated periodically to reverse the movement of sludge through the reactor.
- The last stage becomes mixed when the flow is reversed.

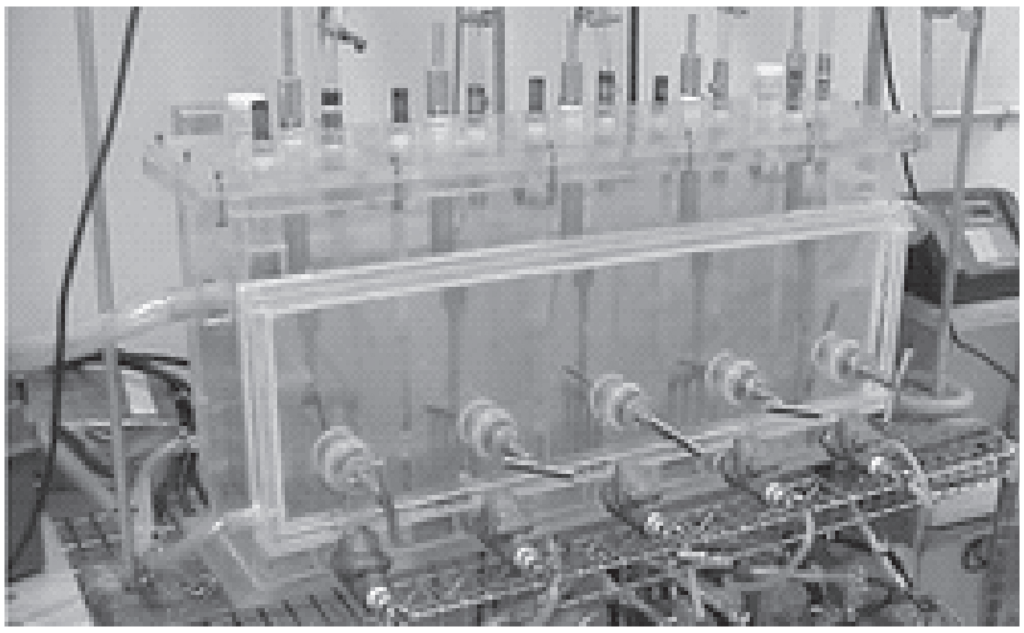


Fig.: 10.3

APPLICATION

- Biological treatment of wastewater with very low to very high strength of wastewater
- Sewage treatment for medium to large towns/ cities.
- Treatment of distillery spent wash / pulp mill black liquor.
- Highly efficient to treat wastewater with low organic loading.

DESIGN CRITERIA

- Raw effluent data such as BOD, COD, TSS, TDS, Oil & Grease
- Organic loading rate

CHAPTER-11

ADVANCE TREATMENT

➢ ADVANCED WASTEWATER TREATMENT

- Advanced wastewater treatment is defined as the methods and processes that remove more contaminants from wastewater than the conventional treatment. The term advanced treatment may be applied to any system that follows the secondary, or that modifies or replaces a step in the conventional process. The term tertiary treatment is often used as a synonym; however, the two are not synonymous. A tertiary system is the third treatment step that is used after primary and secondary treatment processes.
- Important role in Zero Liquid Discharge theory in future for water reuse purposes.

Types of Advanced Treatment :

Water Filtration

- When we refer to water purification, it makes little sense to discuss the subject without first identifying the contaminants that we wish to remove from water. **Also,** the source of the water is of importance
- Filtration system,
- for the removal of suspended particles and unsettled flocs.
- Types of filtration systems are:
  - Pressure Sand Filter
  - Activated Carbon Filter
  - Dual Media Filter
  - Iron Removal Filter
  - Swimming pool Filtration

➢ PRESSURE SAND FILTER

- Removes suspended and visible impurities like sand, dust particles & turbidity.
- Consist of pressure vessel including sand layers , pebbles and gravels to enhance filtration
- Water is distributed uniformly from top and filtered water is collected in under drainage

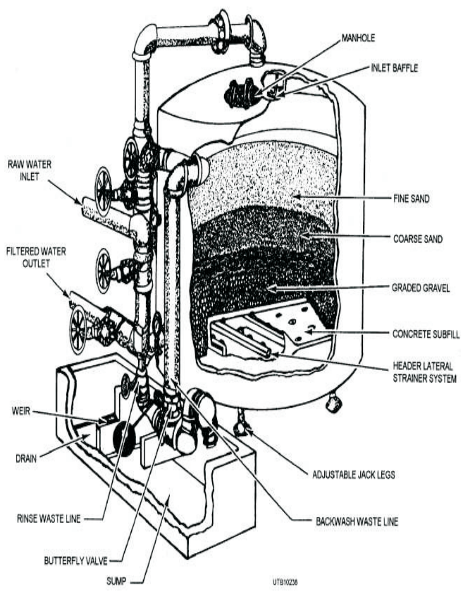
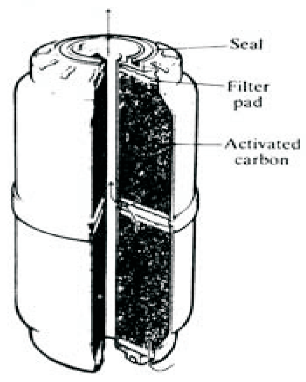


Fig : 11.1

ACTIVATED CARBON FILTER



Activated carbon water filter.

Fig : 11.2

- Used for removal of chlorine and Micro-organisms through adsorption.
- Also effective in removal of color & odor.
- Activated granular carbon is used as a filter bed where free chlorine , color, odor etc are removed.

DUAL MEDIA FILTER

- Combination of PSF and ACF with filtering media as sand and anthracite .
- These dual media filters have high dirt removal capacity.
- Sand media for removal of SS and carbon for the removal of odor , color.

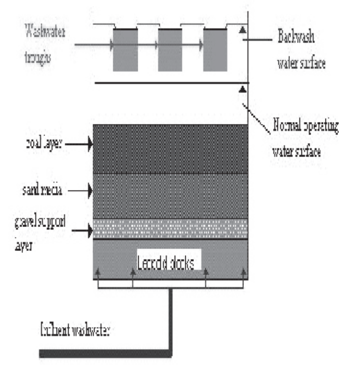


Fig : 11.3

IRON REMOVAL FILTER

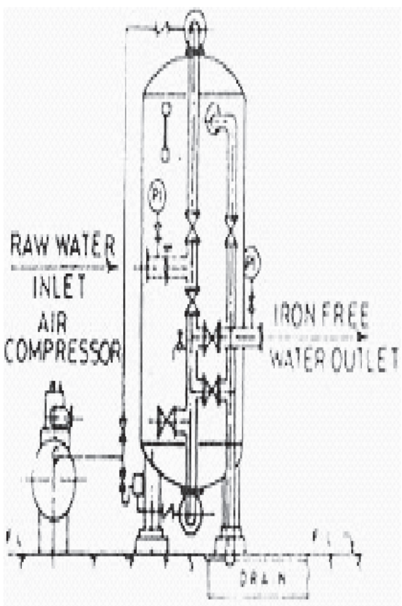


Fig : 11.4

- Removes iron along with other turbidity from the wastewater.
- Removal mechanism based on iron oxidation followed by sand filtration.
- Iron removal filter is processed catalytic filtration unit when the raw water passed through the layer of compressed air, processed catalyst & quartz filter media respectively.
- The dissolved ferrous iron salts are converted into insoluble ferric salt and precipitin over the filter bed and then the iron free filtered water comes out.

➢ SWIMMING POOL FILTRATION

- Swimming pool filtration is generally divided in 3 steps:
- Filtration: By use of sand filter, small sediments and debris are removed from water incoming through human contact or rain or air.
- Ozonization: acts as a powerful oxidant , to destroy algae , bacteria ,inactive viruses and other contaminants present in water.
- Chlorination: for disinfection purposes , which kills harmful micro-organisms that can be harmful to health.

➢ DISINFECTION-ELECTRO CHLORINATOR

- Low capacity system which produces sodium hypochlorite from salt water, by the process of electrolysis.
- Sodium hypochlorite acts as a strong disinfectant for drinking water and wastewater.

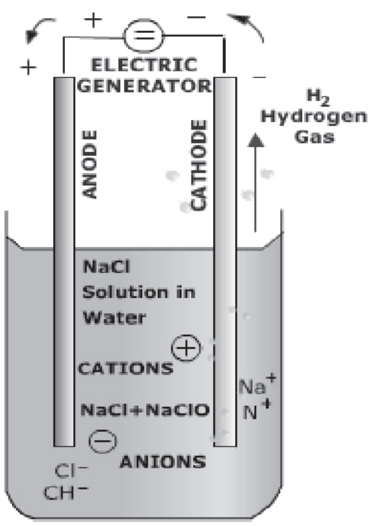


Fig : 11.5

➢ ELECTRO COAGULATION

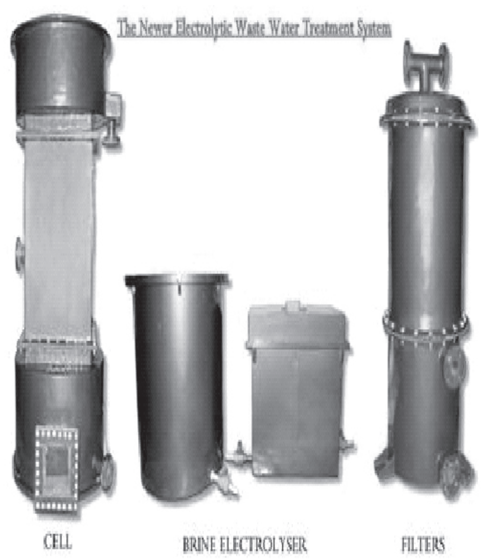


Fig : 11.6

- Treating the effluent by passing electricity-technique known as Electro dialysis.
- The current destabilizes dissolved colloidal particles and alters the charge on suspended particles permitting their coagulation, floatation and separation.
- Removes color , odor, SS, organic, oil and grease etc..

➢ ELECTRO COAGULATION

- ***Special Features Of The Process:***
- Chemical Free, Non Biological
- Modular In Construction
- Custom Designed
- Easily Expandable
- Designed For Continuous Operation
- Can Be Retrofitted In The Existing Facility
- Small Foot Print
- ***Advantages:***

Treatment of-

- Raw Water
- Swimming Pool
- Sewage Waste Water
- Cooling Tower &
- Industrial Effluent

➢ COMPARISON OF ELECTROLYTIC PROCESS WITH CHEMICAL PROCESS

Electrolytic process

- Chemical Free
- Does not Increase TDS
- Eliminates Hazardous Elemental Chlorine
- Eliminates Procurement, Storage and Dosing of Chemicals
- Generates Low Volume of Sludge with Better Dewatering
- Compact Plant with Small Foot Print

Chemical process

- Chemicals Added
- Increases TDS
- Uses Hazardous Elemental Chlorine
- Chemicals are to be Procured, Stored, Prepared and Dosed
- Generates High Volume sludge
- Large Plant with Big Foot Print

➢ ULTRA FILTRATION

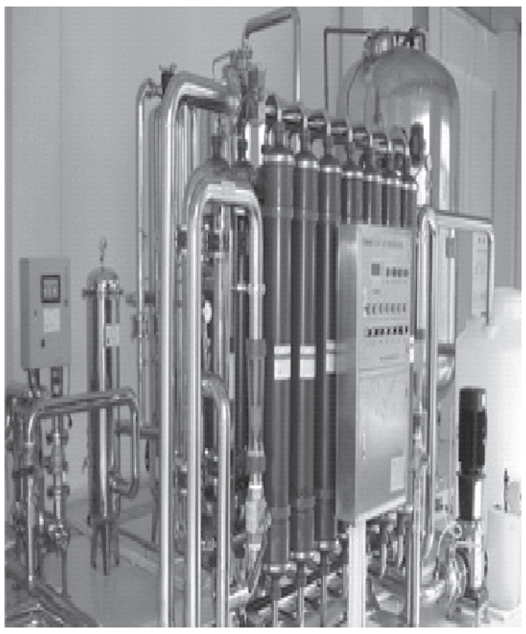


Fig : 11.7

- Ultrafiltration (UF) is a pressure-driven barrier to suspended solids, bacteria, viruses, endotoxins and other pathogens to produce water with very high purity and low silt density.
- Typically, Ultrafiltration will remove high molecular-weight substances, colloidal materials, silt (SDI), and organic and inorganic polymeric molecules.
- It serves as a pretreatment for surface water, seawater, and biologically treated municipal effluent before reverse osmosis and other membrane systems.
- Ultrafiltration is a separation process using membranes with pore sizes in the range of 0.1 to 0.001 micron.

➢ REVERSE OSMOSIS

Fig : 11.8

- Reverse osmosis is also a process of separation. The feed water stream is separated into a stream of purified water and a stream of concentrated solutes and particulates. This is as compared to standard filtration where the entire feed stream passes through the membrane pores, leaving the particulates embedded in the filter media.
- Reverse Osmosis are field proven, highly reliable and cost effective answer to treat a wide range of brackish water and sea water. Designed with flexibility, the series utilize state-of-the-art spiral wound reverse osmosis membranes to suit a given application. These systems can remove 90 - 98% of total dissolved salts.

➢ WATER SOFTENING

- Hardness causing multevallent ions – Calcium and Magnesium lead to the formation of scale which in turn results into clogging of pipelines and fixtures, scaling of boiler tubes, cooling towers fins, solar heater coils or stains on fabric.
- Basic principle: Ion exchange , through a resin where the harness ions exchange with the sodium ions in resin and eventually produce soft water.
- Zeolite : a type of resin used for Ion Exchange purposes.

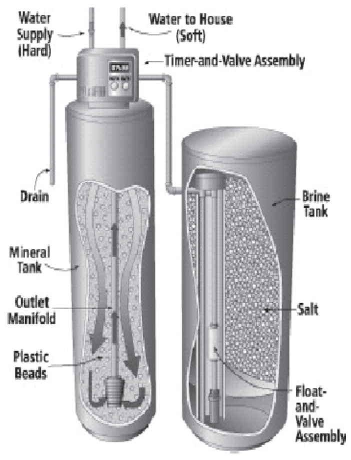


Fig : 11.9

Application :

- Boiler Feed
- Cooling Tower Make-up.
- Air Conditioning Plant.
- Textile Processing.
- Beverage Production.
- Filter High Quantity Of Water
- Thermoelectric Power Plants
- Low Pressure Boiler Feed
- Dairies
- Food And Beverages
- Hotels And Restaurants
- Laundries

DESIGN CRITERIA

- Raw effluent data for hardness
- Final treated effluent quality
- Regeneration period
- Output between two regeneration(OBR)

ADVANCE TREATMENT FOR OIL & GREASE REMOVAL

➢ DAF (DISSOLVED AIR FLOTATION)

- DAF system separates and removes suspended and colloidal solids , as well as fats, oils and grease from liquid
- It is designed to meet the needs of a wide variety of industrial markets including food processing , refining, metals, mining , pulp and paper, chemicals , tanning and others , the DAF system is also used in municipal applications as a sludge thickener
- The most common procedure is that of dissolved air flotation (DAF), in which the waste stream is first pressurized with air in a closed tank. After passing through a pressure-reduction valve, the wastewater enters the flotation tank where, due to the sudden reduction in pressure, minute air bubbles in the order of 50- 100 microns in diameter are formed.
- As the bubbles rise to the surface, the suspended solids and oil or grease particles adhere to them and are carried upwards.
- It is common practice to use chemicals to enhance flotation performance.
- One alternate design involves the recycling of part (10-30%) of the treated water.
- All systems contain a mechanism for removing the solids that may settle to the bottom of the flotation tanks, usually by a helical conveyor placed in the conical bottom.
- The main advantage claimed of DAF systems is the faster rate at which very small or light suspended solids can be removed in comparison with settling.
- Performance of DAF systems has been reported to be dependent on several factors:
  - the solids concentration
  - the ratio of air to solids (A/S)
- Key factors in the successful operation of DAF units are
  - the maintenance of proper pH
  - proper flow rates
  - the continuous presence of trained operators

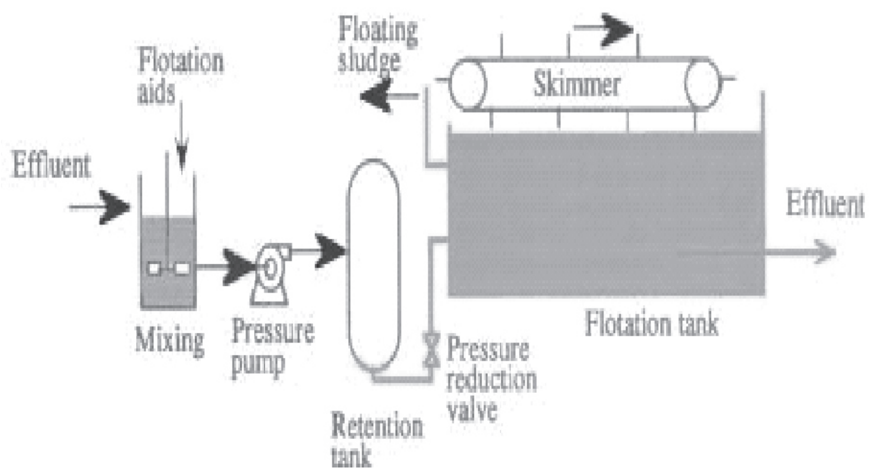


Fig : 11.10

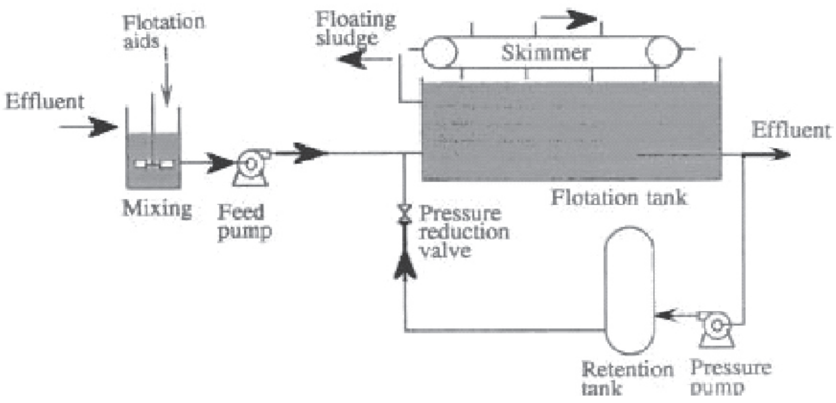


Fig : 11.11 • Diagram of a DAF system with recycle

The Davco Products Dissolved Air Flotation (DAF) system separates and removes suspended and colloidal solids, as well as fats, oils, and grease from liquid. Designed to meet the needs of a wide variety of industrial markets including food processing, refining, metals, mining, pulp and paper, chemicals, tanning, and others, the DAF system is also used in municipal applications as a sludge thickener.

Fig : 11.12

Advantages of Circular Tanks Over Rectangular Tanks :

- Minimized maintenance due to fewer moving parts,no submerged bearings,sprockets or chains.
- Flexible nozzle orientation.
- Lower installed costs.
- More complete separation due to varying velocity through the tank.

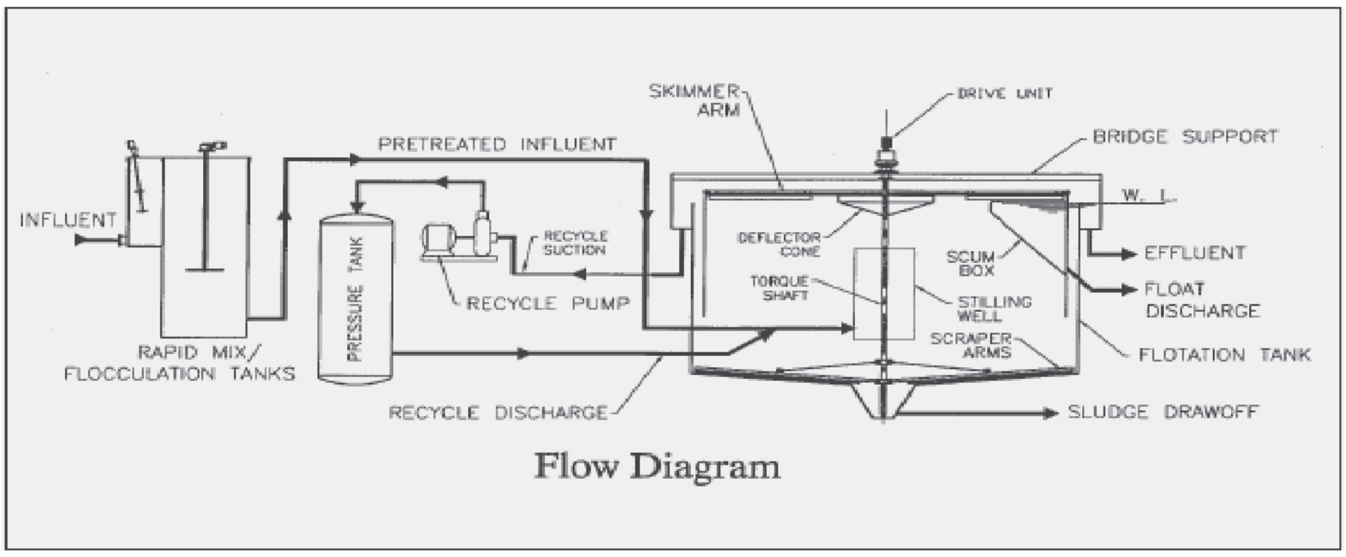


Fig : 11.13

COMPARISON OF TECHNOLOGIES

- Different processes are subjected to a qualitative analysis as a first step to find those that will meet the project requirement. A following table shows some merits and demerits of the technologies.

Process	Merits	Demerits
Activated Sludge Process (Conventional	• Process flexibility • Reliable operation • Proven track record in all plant sizes • Low order emission • Energy production	• High energy consumption • Skilled operators needed • Energy production • No nutrient removal
Extended Aeration	• Simple and flexible operation • Ability to absorb shock loads • Not high operator oversight required	• High operating costs • No energy production • No nutrient removal
Membrane Bioreactor	• Excellent effluent quality for reuse • Nutrient Removal possible • Stabilized sludge • Low footprint (area) requirement • Ability to absorb shock loads	• High construction costs • Very high operation cost • High membrane replacement cost • High automation • No energy production
Moving Bed Bio Reactor	• Low area requirement • Sludge recirculation not needed • Smaller area • Satisfactory effluent quality	• High energy consumption • Plastic media must be cleaned periodically ,with some breakage • Suitable for small applications • Skilled operators needed • No energy production • Effluent quality not upto the mark in India. • No nutrient removal
Sequencing Batch Reactor	• Excellent effluent quality • Smaller footprint because of absence of primary, secondary clarifiers and digester • Recent track record available in large applications in India also • Excellent effluent quality • Biological nutrient (N&P) removal • High degree of coliforms removal • Less chlorine dosing required • Ability to absorb shock hydraulic and organic loads	• Comparative energy consumption • Comparative automation • High skilled operators needed • No energy production

Process	Merits	Demerits
Upflow Anaerobic Sludge Blanket +FPU	• Simple operation • Energy production	• Large Land requirement • More man -power require for O & M • Effluent quality is not upto the mark • High chlorine dosing required. • No nutrient removal
Activated Sludge Process (with Nitrification-Denitrification & Bio-P Removal)	• Process flexibility • Reliable operation • Proven track record in all plant sizes • Low odor emission • N&P Removal • Energy production	• High energy consumption • Skilled operators needed • Fairly large area requirement

Table : 11.1

Technology Selection In STP :

- Objective1 → Reduce Capital Cost → UASB or ASP or MBBR
- Objective2 → Reduce Space → SBR or MBR or MBBR
- Objective3 → Reduce O & M cost → UASB or SBR
- Objective4 → Recycle reuse → SBR or MBR

CHAPTER-12

SLUDGE MANAGEMENT

INTRODUCTION

- In the context of wastewater treatment residual is used to refer “sludge”.
- The term sludge refers to the solids that are settled and separated during wastewater treatment.
- It is necessary to treat properly or dispose the sludge generated during the various stages of wastewater treatment like primary sedimentation, secondary sedimentation and sludge generated from advanced (tertiary) treatment,
- The sludge generated during the wastewater treatment can be classified into three categories:
- Primary sludge
- Secondary sludge
- Tertiary sludge

PRIMARY SLUDGE

- Sludge settled in primary settling tanks comes under this category which contains 3% to 7% solids out of which approximately 60% to 80% are organic.

SECONDARY SLUDGE

- It consists mainly of microorganism containing 75% to 90% organic fraction and remaining inert materials.

TERTIARY SLUDGE

- The nature of sludge from the tertiary (advanced) treatment process depends on the unit process followed like membrane processes or chemical methods, etc.
- Chemical sludge from phosphorus removal is difficult to handle and treat.
- Tertiary sludge from biological nitrification and denitrification is similar to waste activated sludge.
- Organic sludge originates from various sources such as PST, SST OF ASP, SST OF TF, etc. PST and SST sludge usually have 65% -75% volatile solids while sludge from tf of SST will have 45 to 70% volatile solids.
- The dry solids content of primary and secondary sludge after thickening is about 4 to 6% and specific gravity of 1.01.
- The separation of water is difficult from undigested sludge.
- After digestion sludge have volatile solids of about 32 to 48%, dry solids of 8 to 13%, and specific gravity of 1.03 to 1.05 and fuel value is about 8100 to 9300 KJ/Kg of dry solids
- Generally PST and SST sludge is thickened before digestion to reduce volume of sludge.
- Sludge treatment is an important aspect of wastewater treatment and account for 40 to 45 % of the capital and operating costs.

SLUDGE THICKENING

- Sludge thickening or dewatering is adopted for reducing the volume of sludge and increasing the solid contents this will help in following:
- Increasing the loading on the digester, requiring lesser digester volume,
- Increase feed solids concentration to vacuum filters,
- Economize transport and handling cost of sludge within the plant and final disposal,
- Minimize land required and handling cost for final disposal of the digested sludge on land, and
- Save fuel if incineration is practiced.
- Sludge thickening or dewatering is adopted for reducing the volume of sludge and increasing the solid contents. this will help in following:
- Increasing the loading on the digester, requiring lesser digester volume,
- Increase feed solids concentration to vacuum filters,
- Economize transport and handling cost of sludge within the plant and final disposal,
- Minimize land required and handling cost for final disposal of the digested sludge on land, and
- Save fuel if incineration is practiced.

SLUDGE DEWATERING

- The digestion of the primary or mixed sludge will bring down the water content to about 90%;
- However, treatment is necessary to reduce the water content further.
- Applied on the sludge drying beds, the water content of the sludge can be reduced to around 70%.
- Presence of excess oil and grease will interfere with this process. sludge drying beds require
- Places where land is not available other alternatives such as, mechanical dewatering on vacuum
- Filters, filter press or centrifuge followed by heat drying or incineration could be used after
- Sludge conditioning.

AEROBIC AND ANEROBIC DIGESTION

Fig. : 12.1

Types of Digestion :

- Aerobic digestion
  - Use “Free” Oxygen
- Anaerobic digestion
  - No “Free” Oxygen

➢ AEROBIC DIGESTION

- **Advantages**
  - Effective for “secondary”
  - Simple operation
  - No hazardous gas production
- **Disadvantages**
  - Higher operating costs
  - High energy demands
  - No burnable gas
  - Higher organic content

ANAEROBIC DIGESTION PROCESS

"TWO-STAGE" Process
OR
"Two Phase" Process
Two Types of Bacteria
Each Relying On The Other

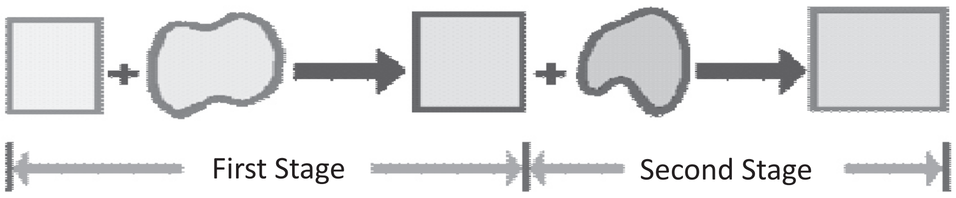


Fig.: 12.2

- Organic Material Changed
- By Acid Forming Bacteria
- To Simple Organic Material

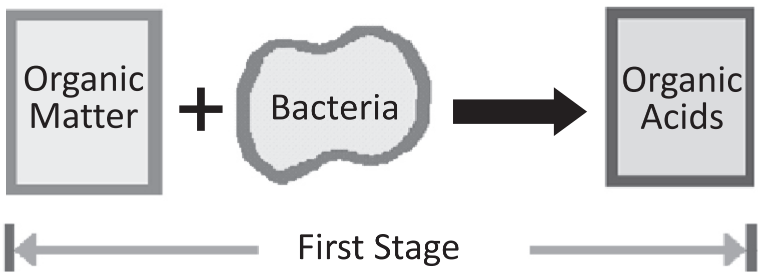


Fig.: 12.3

- Methane-Forming Bacteria
- Use Organic Acids
- Produce Carbon Dioxide and Methane

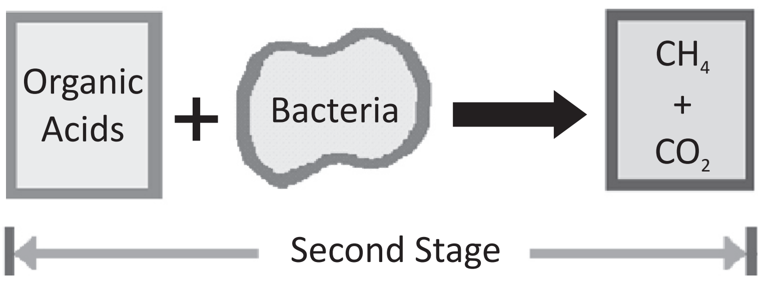


Fig.: 12.4

➢ ANAEROBIC DIGESTION

- Anaerobic digestion is a collection of processes by which microorganisms break down iodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste and/or to produce fuels.
- Much of the fermentation used industrially to produce food and drink products, as well as home fermentation, uses anaerobic digestion.
- Anaerobic digestion occurs naturally in some soils and in lake and oceanic basin sediments, where it is usually referred to as "anaerobic activity"
- The digestion process begins with bacterial hydrolysis of the input materials. Insoluble organic polymers, such as carbohydrates, are broken down in to soluble derivatives that become available for other bacteria.
- Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, andorganic acids. These bacteria convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide.
- Finally,methanogens convert these products in to methane and carbon dioxide.
- The methanogenic archaea populations play an indispensable role in anaerobic wastewater treatments.
- It is used as part of the process to treat biodegradable waste and sewage sludge.
- As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere.
- Anaerobic digesters can also be fed with purpose-grown energy crops, such as maize.
- Anaerobic digestion is widely used as a source of renewable energy. The process produces biogas, consisting of methane, carbondioxide and traces of other 'contaminant' gases.This biogas can be used directly as fuel, in gas engines or upgraded to natural gas-quality biomethane.

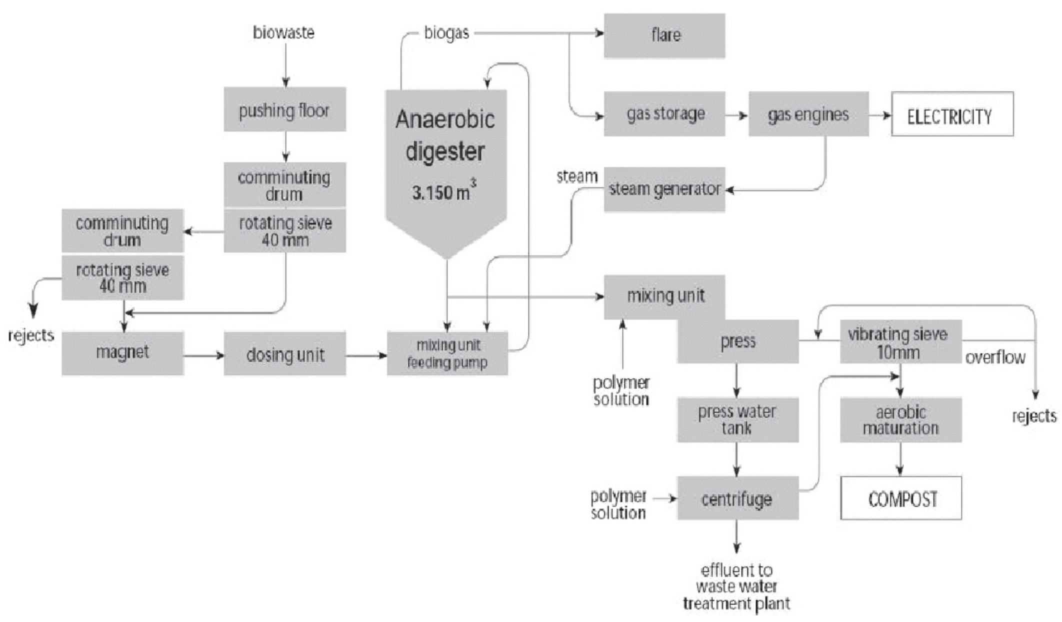


Fig.: 12.5

PROCESS DESCRIPTION

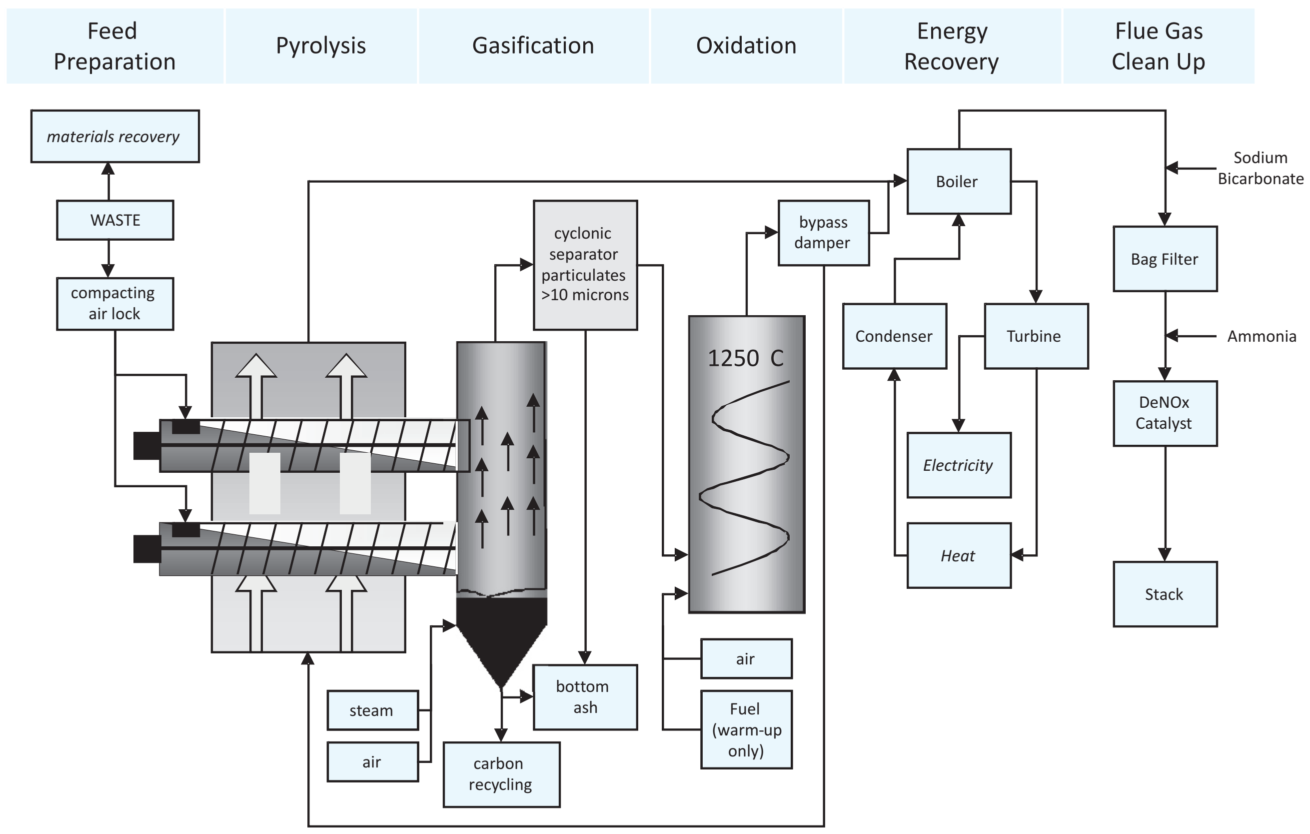


Fig.: 12.6

Fig.: 12.7 Anaerobic Digester

Anaerobic Digestion Process :

Products of Digestion

1. Gases
   - Methane (CH_4)
   - Carbon Dioxide (CO_2)
2. Scum
   - Lighter Solids
3. Supernatant
   - Liquid Removed
4. Digested Sludge
   - "Stabilized"

Anaerobic Digestion :

Advantages

- Low operating costs
- Proven effectiveness
- Burnable gas produced

Disadvantages

- Long start-up time
- Affected by changes in loading and conditions
- Explosive gas produced

Digestion Factors :

1 Bacteria
2. Food
3. Loading
4. Contact
5. Environment

Operation And Control:

1. Bacteria

- Maintain Adequate Quantity
  - Don't Remove Too Much
  - Don't Displace Too Much
  - Plan For Re-Start

2. Food

- Minimize Amount of Inorganics Entering
  - Industrial Discharges Grit Systems
  - Eliminate Toxic Material

3. Loading

- Amount
  - Applied to the Treatment Process
  - Related to the SIZE of the System
- Pump Thick Sludge
  (High % Total Solids)
  - Excess Water Requires More Heat
  - Excess Water Reduces Holding Time
  - Excess Water Removes Bacteria and Buffers
- Pump Several Times per Day
  - Uniform Digester Loading
  - Uniform Plant Operations

4 Contact (Mixing)

- Contact
  - Bacteria and Food
- Heat Distribution
  - Even Throughout
- Minimize Settling
  - Reduces Available Volume
- Minimize Scum
  - Operational Problems

5 Environment

- Temperature Control
  - 90 to 95°F
  - Methane Formers Very Sensitive to Changes
  - Good Mixing Essential

Digestion Factors

Environment

- Anaerobic
  - No Oxygen
- Temperture
  - Mesophilic-Constant
- pH
  - Best - 6.8 to 7.2
- Volatile Acids

  Not Excessive
- Buffers (alkalinity)
  - Incoming Sludge and Created
- Toxic Materials
  - Inhibit Biological Activity

CHAPTER-13

PUBLIC HEALTH & HYGIENE

GENERAL HYGIENE

- **Health** is defined in the WHO constitution of 1948 as: a state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity.
- **Hygiene** is the science of preventing and protecting the health of people through control of the environment.
- **Environment** is our surroundings described as physical surroundings (air, water and land), biological surroundings (animals and plants), and social surroundings.

CONVENTIONAL SANITATION

- Due to disease risks caused by faecal wastewater, in large European cities sewers were constructed to drain the wastewater away from the people's surroundings to the nearby water courses, and ultimately into the sea. Later it was found that discharging raw wastewater had deteriorated aquatic environment of the receiving water body, and at the same time it caused diseases to the people, who received their drinking water from the same river downstream. Because of drinking water contamination, epidemics of cholera had periodically caused heavy losses of life in large European cities.
- The outbreak of cholera in 1892 for instance, took place all over in Hamburg, where drinking water supply was extracted from the river Elbe. To protect these rivers from the pollution as well as the public health from water borne diseases, the wastewater was since then treated at the end of the sewer before discharging it into the river. This tradition has been widely established as a standard way of managing wastewater world wide.
- However, most of the wastewater is discharged without any treatment mostly in developing countries.
- Centralised wastewater management systems have been built and operated for more than hundred years. In the mean time, because of advanced technological development, the wastewater management has reached a high standard in many industrialised countries.
- However, in developing countries the present situation is still similar to that of the currently industrialised countries in the 19th century in many respects.
- About 95 % of wastewater in developing countries is still discharged without any treatment into the aquatic environment . This contributes largely about 1.2 billion people without access to clean drinking water. Almost 80 % of diseases throughout the world are water-related. Water-borne diseases account for more than 4 million infant and child deaths per year in developing countries.

- The following factors are lethal to most of the pathogens:
  - high pH (> 9)
  - Low moisture contain (< 25%)
  - High temperature (> 55 OC) over more than 10 hours
  - Long retention time (> 6 months)
  - Ammonia and high salt content
  - Limited nutrients (competition for food)
  - predator-prey relationships
  - antagonism
  - High pH can be obtained by adding alkaline material such as ash or lime (but lime is not preferable) that reduces the moisture additionally. Moisture can be lowered by drying.
  - High ammonia and salt can be obtained from urine.

SUSTAINABLE SANITATION

If the ecological sanitation can fulfil furthermore as well as social and ecological requirements, it is called "sustainable sanitation". Such a sanitation is also form the hygienic point of view desirable, due to the fact, that it includes also other aspects, which save health in order to a risk management. Some further aspects of sustainable sanitation are (see figure):

- Closing and separating the cycles of water and nutrients; avoidance of hygienic problems due to the separation of faeces from the water cycle
- Reclamation of nutrients (phosphorus and nitrogen) for agricultural use and hence saving of resources and energy (for the production of artificial fertilizer)
- Considerable savings of freshwater through the use of water saving toiletsystems (vacuum, separating or dry toilets)
- Energy production (biogas) instead of energy consumption (for carbon degradation in sewage plants)
- Savings of construction, operation and maintenance costs compared to the conventional central sewerage systems
- Sophisticated modular system, which can be adapted perfectly to local social, economical and environmental conditions
- Easier operation and maintenance compared to centralized technology; local job creation

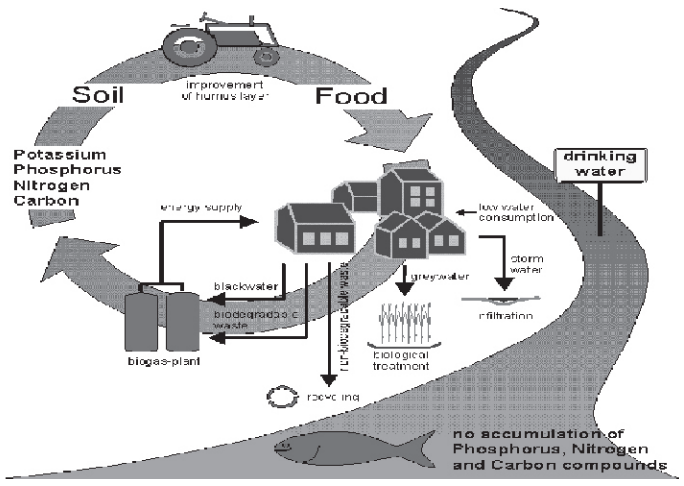


Fig. : 13.1 Sustainable Sanitation System

CHAPTER-14

CLASSIFICATION OF WATER POLLUTANTS AND EFFECTS ON ENVIRONMENT

WATER POLLUTANTS

- The various types of water pollutants can be classified in to following major categories:
- Organic pollutants,
- Pathogens,
- Nutrients and agriculture runoff,
- Suspended solids and sediments (organic and inorganic),
- Inorganic pollutants (salts and metals),
- Thermal pollution, and
- Radioactive pollutants.

ORGANIC POLLUTANTS

Organic pollutants can be further divided into following categories:

OXYGEN DEMANDING WASTES:

- The wastewater such as, domestic and municipal sewage, wastewater from food processing industries, canning industries, slaughter houses, paper and pulp mills, tanneries, breweries, distilleries, etc.
- Have considerable concentration of biodegradable organic compounds either in suspended, colloidal or dissolved form.
- These wastes undergo degradation and decomposition by bacterial activity.
- The dissolved oxygen available in the water body will be consumed for aerobic oxidation of organic matter present in the wastewater.
- Hence, depletion of the DO will be a serious problem adversely affecting aquatic life, if the DO falls below 4.0 mg/l.
- This decrease of DO is an index of pollution.

SYNTHETIC ORGANIC COMPOUNDS

- Synthetic organic compounds include synthetic pesticides, synthetic detergents, food additives, pharmaceuticals, insecticides, paints, synthetic fibers, plastics, solvents and volatile organic compounds (VOCs).
- Most of these compounds are toxic and biorefractory organics i.e., they are resistant to microbial degradation.
- The detergents can form foams and volatile substances may cause explosion in sewers. polychlorinated biphenyls (PCBs) are used in the industries since 1930s which are complex mixtures of chlorobiphenyls.
- Being a fat soluble they move readily through the environment and within the tissues or cells.
- Once introduced into environment, these compounds are exceedingly persistent and their stability to chemical reagents is also high.

OIL

- Oil is a natural product which results from the plant remains fossilized over millions of years, under marine conditions.
- It is a complex mixture of hydrocarbons and degradable under bacterial action, the biodegradation rate is different for different oils, tars being one of the slowest.
- Oil enters in to water through oil spills, leak from oil pipes, and wastewater from production and refineries.

PATHOGENS

- The pathogenic microorganisms enter in to water body through sewage discharge as a major source or through the wastewater from industries like slaughter houses.
- Viruses and bacteria can cause water borne diseases, such as cholera, typhoid, dysentery, polio and infectious hepatitis in human.

NUTRIENTS

- The agriculture run-off, wastewater from fertilizer industry and sewage contains substantial concentration of nutrients like nitrogen and phosphorous.
- These waters supply nutrients to the plants and may stimulate the growth of algae and other aquatic weeds in receiving waters.
- Thus, the value of the water body is degraded. in long run, water body reduces do, leads to eutrophication and ends up as a dead pool of water.
- In freshwater systems, eutrophication is a process whereby water bodies receive excess inorganic nutrients, especially N and P, which stimulate excessive growth of plants and algae.
- Two major nutrients, nitrogen (N) and phosphorus (P), occur in streams in various forms as ions or dissolved in solution.
- Aquatic plants convert dissolved inorganic forms of nitrogen (nitrate, nitrite, and ammonium) and phosphorus (orthophosphate) into organic or particulate forms for use in higher trophic production.
- The main effects caused by eutrophication can be summarized as follows:
- 1. species diversity decreases and the dominant biota changes
- 2. plant and animal biomass increase
- 3. turbidity increases
- 4. rate of sedimentation increases, shortening the lifespan of the lake, and
- 5. anoxic conditions may develop.

SUSPENDED SOLIDS AND SEDIMENTS

- These comprise of silt, sand and minerals eroded from land.
- These appear in the water through the surface runoff during rainy season and through municipal sewers.
- This can lead to the siltation, reduces storage capacities of reservoirs.
- Presence of suspended solids can block the sunlight penetration in the water, which is required for the photosynthesis by bottom vegetation.
- If the deposited solids are organic in nature, they will undergo decomposition leading to development of anaerobic conditions.

INORGANIC POLLUTANTS

- Apart from the organic matter discharged in the water body through sewage and industrial wastes, high concentration of heavy metals and other inorganic pollutants contaminate the water.
- These compounds are non-biodegradable and persist in the environment.
- These pollutants include mineral acids, inorganic salts, trace elements, metals, metals compounds, complexes of metals with organic compounds, cyanides, sulphates, etc.
- The accumulation of heavy metals may have adverse effect on aquatic flora and fauna and may constitute a public health problem where contaminated organisms are used for food.
- Tlgal growth due to nitrogen and phosphorous compounds can be observed.
- Metals in high concentration can be toxic to biota e.g. Hg, Cu, Cd, Pb, As, and Se.
- Copper greater than 0.1 mg/l is toxic to microbes.

THERMAL POLLUTION

- As a result of hot water discharge, the temperature of water body increases.
- Rise in temperature reduces the DO content of the water, affecting adversely the aquatic life.
- When organic matter is also present, the bacterial action increases due to rise in temperature; hence, resulting in rapid decrease of DO.

RADIOACTIVE POLLUTANTS

- Radioactive materials originate from the following:
- Mining and processing of ores,
- Use in research, agriculture, medical and industrial activities, such as I131, P32, Co60, Ca45, S35, C14, etc.
- Radioactive discharge from nuclear power plants and nuclear reactors, e.g., Sr90, cesium
- Cs137, plutonium Pu248, uranium-238, uranium-235,
- Uses and testing of nuclear weapons.
- These isotopes are toxic to the life forms; they accumulate in the bones, teeth and can cause serious disorders.
- The safe concentration for lifetime consumption is 1 x 10-7 microcuries per ml.
- The summary of various pollutants and their adverse effect on the environment is presented in below table.
- The major impacts have been described, however there are additional adverse effects of release of these pollutants in the environment.

Sr. No.	Pollutants	Impact
1.	Organic pollutants i)Oxygen Demanding wastes: ii)Synthetic organic pollutants iii) oil	Depletion of the DO will be a serious problem adversely affecting aquatic life, if the DO falls below 4.0 mg/L. Most of these compounds are toxic and biorefractory organics. It also make water unfit for different uses. This pollutant is also responsible for endangering water birds and coastal plants due to coating of oils and adversely affecting the normal activities which cause reduction of light transmission and photosynthesis.
2.	Pathogens	Number of diseases transmitted by pathogens available in wastewater
3.	Nutrients	When these are disposed in aquatic environment, it can lead to growth of undesirable aquatic life. When it discharged on land it causes groundwater pollution.
4.	Thermal pollutants	When organic matter is also present, the bacterial action increases due to rise in temperature; hence, resulting in rapid decrease of DO. It also results in thermal stratification which alters spectrum of organisms.
5.	Radioactive pollutants	These isotopes are toxic to the life forms; they accumulate in the bones, teeth and can cause serious disorders
6.	Suspended solids and sediments	Presence of suspended solids can block the sunlight penetration in the water, which is required for the photosynthesis by bottom vegetation. Finer suspended solids such as silt and coal dust may injure the gills of fishes and cause asphyxiation.
7.	Inorganic pollutants	These pollutants include mineral acids, inorganic salts, trace elements, metals, metals compounds, complexes of metals with organic compounds, cyanides, sulphates, etc. They have adverse effect on aquatic flora and fauna and may constitute a public health problem.

Table : 14.1

CHAPTER-15

OPERATION & MAINTENANCE OF STP

OPERATION & MAINTENANCE PROBLEMS IN VARIOUS EQUIPMENT OF STP

O&M Considerations For Bar Screen :

- Check and clean the bar screen at frequent intervals
- Do no allow solids to overflow/escape from the screen
- Ensure no large gaps are formed due to corrosion of the screen
- Replace corroded/unserviceable bar screen immediately

Troubleshooting

Problem	Cause
Large articles pass Through, and chock the pumps	Poor design / poor operation / screen damaged
Upstream water level is much higher than downstream level	Poor operation (inadequate cleaning)
Excessive collection of trash on screen	Poor operation
Excessive odor	Poor operation / trash disposal practices

Table : 15.1

O&M Considerations Of Oil And Grease/ Grit Trap :

- Check and clean trap at frequent intervals
- Remove both settled solids (at bottom) and the floating grease
- Do not allow solids to get washed out of the trap
- Do not allow oil and grease to escape the trap
- Redesign the trap if solids and grease escape on a regular basis, despite good cleaning practices

Troubleshooting

Problem	Cause
Oil and grease pass through the trap	Poor design/ poor operation
An excessive amount of solids passes through the trap	Poor design/ poor operation
Excessive odor	Poor operation/ waste disposal practices

Table : 15.2

O&M Considerations of Equalization Tank

- Keep air mixing on at all time
- Ensure that the air flow/ mixing is uniform over the entire floor of the tank. adjust the placement of diffusers and the air-flow rate as needed.
- Keep the equalization tank nearly empty before the expected peak load hours (otherwise it will overflow)
- Check and clean clogged diffusers at regular intervals
- Manually evacuate settled muck/ sediments at least once in a year

Troubleshooting

Problem	Cause
Insufficient mixing/ aeration	Poor design, engineering
Excessive odor	Poor design, engineering
Insufficient capacity to handle peak flows	Poor design
Usable capacity reduced due to solids accumulation	Poor maintenance

Table : 15.3

O&M Consideration Of Raw Sewage Lift Pumps :

- Switch between the main and standby pump every 4 hours (approximately).
- Switch between the main and standby pump every 4 hours (approximately).
- Check oil in the pump every day; top up if necessary
- Check motor-to-pump alignment after every dismantling operation
- Check condition of coupling and replace damaged parts immediately
- Check for vibrations and tighten the anchor bolts and other fasteners
- Check condition of bearings, oil seals, mechanical seal and replace if necessary
- Completely drain out oil and replace afresh as per manufacturer's recommendation
- Always keep safety guard in its proper position
- Follow the LOTO safety principles while performing maintenance activities
- Ensure discharge of raw sewage into the aeration tank is visible and can be monitored
- Maintain the flow rate at designed level (no tampering with the bypass valve)

Troubleshooting Of Sewage Lifting Pumps :

Problem	Cause
Excessive noise	Poor engineering / maintenance
Excessive vibration	Poor engineering / maintenance
Overheating	Poor maintenance
Loss in efficiency of puming	Poor maintenance

Table : 15.4

O&M Considerations Of Sedimentation Tank :

If Properly Designed, Engineered And Constructed, Clarifiers Call For Very Little Attention In Terms Of Operation And Maintenance. Indeed, The Unmechanized (hopper-bottom) Settling Tanks May Be Said To Be Zero- Maintenance Units. Some Parts Of The Mechanical Rake (such As The Motor, Gearbox Etc.) Call For Only Routine Maintenance. The Sacrificial Rubber Squeegees Sweeping The Floor Of The Clarifier Need To Be Checked And Replaced, Possibly Once In Two Years.

Troubleshooting

SIGN & SYMPTOMS	POSSIBLE CAUSES	SUGGESTED ACTIONS
Floating sludge in all tanks	Accumated sludge decomposing in the tank and buoyed to the surface	Removed sludge more completely and more often
Floating sludge not in all tank	Affected tank receiving to much sewage	Reduce a flow to affected tank
Bubbles rising in tank	Septic conditions	Report and empty tank completely as soon as possible
Contains black and odorous material	Septic sewage or strong digester supernatant	Take action to eliminate septicity or improve digester operation to improve quality of supernatant
Excessive settling in inlet channels	Velocity to low	Reduce cross sectional area by installing inner wall or agitated with air or water to prevent deposition
Excessive suspended matter in effluent over tanks	Accumulated sludge flow through tank to fast or humus sludge returned to fast	Clean tanks more often or reduce pumping rates
Sludge pipes choke	Sludge to thick or sludge contains grit	Clean grit chamber more often. Change sludge piping necessary
Sludge hard to remove from hopper	High contain of grit or clay. Low velocity in withdrawal lines	Reduce grit contents.

Table : 15.5

Troubleshooting Of Aeration Tank :

- **Operation And Maintenance Considerations**
- Operation considerations include maintaining the correct design level of MLSS (biomass concentration) in the aeration tank. Problems arise both in the case of excess or shortage of biomass, causing an imbalance, leading to failure of the process. The next chapter shows how to maintain the correct design level of MLSS in the aeration tank.
- Visual observation will indicate if there is uniform aeration and mixing over the entire area of the tank. Local violent boiling/ bubbling is indicative of ruptured membranes. Dead zones on the sewage surface indicate that membranes are blocked from the air side or the liquid side. Both conditions call for immediate attention, by cleaning or replacing the membranes.
- Cleaning of membranes is generally carried out by lifting out the defective units and scouring out the adhering materials by high-pressure hosing. Scrubbing with mild acid solution may also be resorted to in case of stubborn encrustation.
- Foaming in the aeration tank may be caused by excessive inflow of detergent-like substances: In a great majority of cases, the cause may be traced to an imbalance in the aeration tank recipe (Food: Microorganisms: Air: Nutrients), and corrective measures may be taken as indicated.

TROUBLESHOOTING

SIGN & SYMPTOMS	POSSIBLE CAUSES	SUGGESTED ACTIONS
Sludge Floating to surface of secondary clarifiers	• Filamentous organisms predominating in mixed liquor (Bulking Sludge).	· Check SVI, if > 150, bulking. · Microscopic examination for the presence of filamentous organisms. · Increase DO in aeration tank, if less than 1.5 mg/L at the effluent end of aerator, · Increase SRT to greater than 6 days. · Increase return sludge & reduce wasting. · Supplement deficiency of nutrients so that BOD to nitrogen ratio is more than 100 mg/L total nitrogen, 1mg/L phosphorus and 0.5 mg/L iron. · Add 5 -10 mg/L chlorine to return sludge until SVI< 150 (should be controlled within 2 -3 days).Microscopically examine sludge to avoid destruction of beneficial organisms during chlorine application. · Increase pH to 7.0 · Add 50 -200mg/L hydrogen peroxide to aeration tank until SVI<150.
Pin-Point flocs in secondary settling tank overflow -SVI is god but effluent is turbid.	· Excessive turbulence in aeration tank	· Measure DO and reduce aeration addition by reducing air blower output or RPM of Surface aerator.
	· Overoxidized sludge	· Check sludge appearance, Increase sludge wasting to decrease MCRT.
	· Anaerobic conditions in aeration tank	· Monitor DO in aeration tank. Increase DO in aeration tank to at least 1.0-1.5mg/L in aeration effluent.
	· Toxic shock load	· Microscopically examine sludge for inactive protozoa. Reseed the sludge with sludge from another plant if possible; enforce industrial waste ordinances. · Stop wasting sludge. · Return rate as high as possible to reestablish cultures.
Very stable dark tan foam an aeration tanks which sprays cannot break up.	· MCRT too long	· Check MCRT, if >9days, may be the cause. Increase sludge wasting so as to reduce MCRT. Increase should be at a modest rate and trends watched carefully.

Thick billows of white sudsy foam on aeration tank.	· **MLSS too low**	· **Check MLSS; Decrease the sludge wasting so as to increase MLSS and MCRT.**
	· Presence of non-biodegradable surface active material.	· If MLSS are appropriate, surfactants are probable cause. Monitor industrial discharge, enforce industrial waste ordinances.
Aeration tank sludge is dark - Sludge blanket lost in secondary clarifier.	· Inadequate aeration, dead zones and septic sludge.	· Measure DO and increase aeration addition by increasing air blower output or adding another blower in service. · Check aeration system piping for leaks. · Clean any plugged diffuser or add more diffuser if possible.
MLSS concentrations differ substantially from one aeration basin to another	· Unequal flow distribution to aeration tanks	· Measure flow to each basin. Adjust valves and/or inlet gates to equally distribute flow.
	· Return sludge distribution unequal to aeration basins.	· Check RAS flow to each basins and adjust it.

Table : 15.6

• TROUBLESHOOTING-BLOWER

SIGN & SYMPTOMS	POSSIBLE CAUSES	SUGGESTED ACTIONS
Unusual noise & vibration	Coupling misalignment	Align coupling with blower at operating temperature according to manufacturer
	Loose nuts, bolts and screws	Tighten
Air system Low pressure	Bypass valve open, leaks of breaks in distribution piping	Close valve, repair leaks or breaks
Air system high pressure	Plugged diffusers	Blow out or remove and clean
Low air flow	High ambient temperature	Add more air, if needed
	Blower air control malfunction	Repair or replace control
System oil low pressure	Oil level too low	Add oil
	Oil filter dirty	Replace
	Check valve sticks open	Replace valve
	Incorrect oil type	Drain and refill with proper oil type

SIGN & SYMPTOMS	POSSIBLE CAUSES	SUGGESTED ACTIONS
Unusual noise & vibration	Coupling misalignment	Align coupling with blower at operating temperature according to manufacturer
	Loose nuts, bolts and screws	Tighten
Air system Low pressure	Bypass valve open, leaks of breaks in distribution piping	Close valve, repair leaks or breaks
Air system high pressure	Plugged diffusers	Blow out or remove and clean
Low air flow	High ambient temperature Blower air control malfunction	Add more air, if needed Repair or replace control
System oil low pressure	Oil level too low Oil filter dirty Check valve sticks open Incorrect oil type	Add oil Replace Replace valve Drain and refill with proper oil type
System oil high pressure	Incorrect oil type	Drain and refill with proper oil type
Oil discharge low pressure	Suction lift too high Air or vapor in oil Coupling slipping on pump shaft	Reduce lift Purge air at filter Secure coupling
Oil temperature low	**Oil cooler water flow too high**	**Throttle water flow**
Oil temperature high	Oil cooler water flow too law Incorrect oil type Insufficient oil circulation	Increase water flow Drain and refill with proper oil type Replace oil filter, check oil lines for restrictions
Hot bearings	Blower speed too high Defective bearings Oil cooler water flow too low	Reduce speed to recommended RPM Check bearings for clearance, hot spots, cracks or other damage. Repair or replace. Increase water flow
Motor doesn't start	Overload relay tipped	Check and reset
Motor noisy	Noisy bearings	Check and lubricate
Motor high temperature	Restricted ventilation Electrical	Check openings and duct work for obstructions. Check for grounded or shorted coils and unbalanced voltages between phases check

Table : 15.7

O&M OF SLUDGE RECIRCULATION

- The manufacturer's O&M manual must be followed with diligence.
- Ensure discharge of sludge recirculation into the aeration tank is visible and can be monitored
- In addition, if an intermediate sludge sump is provided, it is advisable to force-flush the sludge line of the clarifier at frequent intervals, so that the pipe remains clear at all times, and incidence of choking is minimized.

Troubleshooting

Problem	Cause
Excessive noise	Poor engineering / maintenance
Excessive vibration	Poor engineering / maintenance
Overheating	Poor maintenance
Loss in efficiency of pumping	Poor maintenance

Table : 15.8

O&M PROBLEMS IN UASB REACTOR TECHNOLOGY

SIGN & SYMPTOMS	POSSIBLE CAUSES	SUGGESTED ACTIONS
Effluent gutters have more flow on one side than the other	Improper Leveling of the effluent gutter	Adjust Leveling gutter
Water level of over flow weirs of influent distribution system is not equal	Improper adjustment of the distribution boxes or over flow weirs	Adjust position of distribution box or overflow weirs
Gas production lower than normal	Intoxication of the sludge.	• Take sample of sludge and determine methanogenicactivity. • When toxic conditions are still present in sewage, suspend feeding until situation improves. If not, continue feeding and respond as during start-up. continue feeding and respond as during start-up
	Leak in gas collection system Gas meter defect	• Check critical points with soap solution • Repair leaks • Repair Gas meter

During start -up at short HRT the sludge does not improve	Solids loading rate is too high to allow growth of the methanogenic population.	• Check biodegradability of the solids. • Stop feeding of the reactor and allow digestion of the solids until gas production is lowered considerably till it is more or less constant.
	The sewage contains a large fraction of poorly degradable organic solids	• Re-start at HRT=24 hours and lower step-wise until maximum loading is obtained. Most probably the designed HRT cannot be reached.
Effluent turbid	Reactor overloading due to high hydraulic loading rate	Check Flow -rate to reactor. If sludge quality and methanogenic activity of sludge are normal and organic leading rate is normal, then reduce flow-rate.
		When sludge quality and methanogenic activity are normal, then reduce organic loading rate by increasing HRT
		Increase Sludge quantity in the reactor. Allow for improvement of methanoenic activity, for instance by stopping feeding of the reactor
	Reactor overloading due to high organic loading rate Reactor, overloading due to low bio-degradation capacity of the reactor	Check organic loading rate of reactor Check quantity and methanogenic activity of the sludge
Large fraction of solids in effluent	High hydraulic loading rate	Check flow -rate to the plant Reduce flow-rate
	The pump switch levels not properly adjusted	Check switch levels of the pumps
		Adjust switch levels
	Sludge level in the reactor is too high	Check sludge profile and the level of the top of the sludge blanket Discharge sludge
Fast growing floating layer on top of the reactor	High organic loadings rate of the reactor	Organic loading -rate and sludge loading rate Adapt organic loading rate or improve sludge quality
Odours when sludge is applied to sludge drying beds	Inadequate digestion of sludge	Check reactor loading rates Adjust reactor loading rates to design values. In extreme cases stop feeding of reactor until sludge has stabilized.

Table : 15.9

LIFE CYCLE ASSESSMENT FOR SELECTION OF TREATMENT TECHNOLOGIES:

Following Points to be Considered for Life Cycle Assessment :-

Life-cycle assessment (LCA) is a systems-based approach to quantifying the human health and environmental impacts associated with a product's life from “cradle to grave.” A full LCA addresses all stages of the plant life-cycle and should take into account alternative uses as well as associated waste streams, material transport, construction activity, product manufacturing, distribution and use, repair and maintenance, and wastes or emissions associated with a product, process, or service as well as end-of-life disposal, reuse, or recycling.

1. Foot print area:

Environmental footprint analysis is an accounting tool that measures human demand on ecosystem services required to support a certain level and type of consumption by an individual, product, or population. Ecological,materials, carbon, nitrogen, and water footprint analyses are common methods available for calculating environmental footprints.

Ecological Footprint: Ecological footprint measures the amount of land and/or ocean required to support a certain level and type of consumption by an individual or population. This measurement is estimated by assessing the total biologically productive land and ocean areas required to produce the resources consumed and mitigate the associated waste for a certain human activity or population

Materials Footprint: Materials footprint uses material flow analysis to estimate the total material and waste generated in a well-defined system or specific enterprise. This method provides several useful indicators for measuring the mass of materials entering and leaving a defined system boundary, including domestic material consumption, total materials requirements and material intensity.

Carbon Footprint: Carbon footprint is the most developed of the footprint methods. It is a measure of the direct and indirect greenhouse gas emissions caused by a defined population, system, or activity. Carbon footprints can be calculated by taking an inventory of six greenhouse gases: carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons.

Nitrogen Footprint: Nitrogen footprint is a measure of the reactive nitrogen (e.g., nitrous oxides, ammonia, etc.) associated with a population or activity through agriculture, energy use, and resource consumption

Water Footprint: Water footprint measures the total volume of freshwater that is directly or indirectly consumed by a well-defined population, business, or product. Water use can be measured by the volume of water consumed (e.g., the amount evaporated and/or polluted in a given period of time) and is indicative of the water volume required to sustain a given population. The water footprint of a region is the total volume of water used, direct or indirect, to produce goods and services consumed by inhabitants of a region.

2. Capital cost:

It includes the approximate capital cost for construction of new WTP/STP or expansion of existing plants. The cost includes the treatment facilities, piping, clear well storage and administrative and other buildings. The cost does not include acquisition of property, site development or treatment studies.

3. Minimum 10 years O & M period:

The operation and Maintenance period of any new constructed plant shall be minimum 10 years.

4. Energy cost:

It describes the total energy with respect to electricity to be utilized during the construction and efficient working of the plant for at least 10 years after the commissioning of the plant.

5. O & M cost including chemicals:

It represents the operation required for working of the plant and maintenance of the same during the said tenure. It includes chemical cost, labor cost, electricity cost. It also includes changing of chemicals at certain interval, change/repairs of the spares of mechanical and electrical items.

6. Payment return:

It signifies the recovery of the cost of electro-mechanical equipment’s within max. 5 years after the successful commissioning of the plant. Biogas generated from treatment unit can be used for energy generation which can in turn lead to cost recovery too.

WATER TREATMENT PLANT

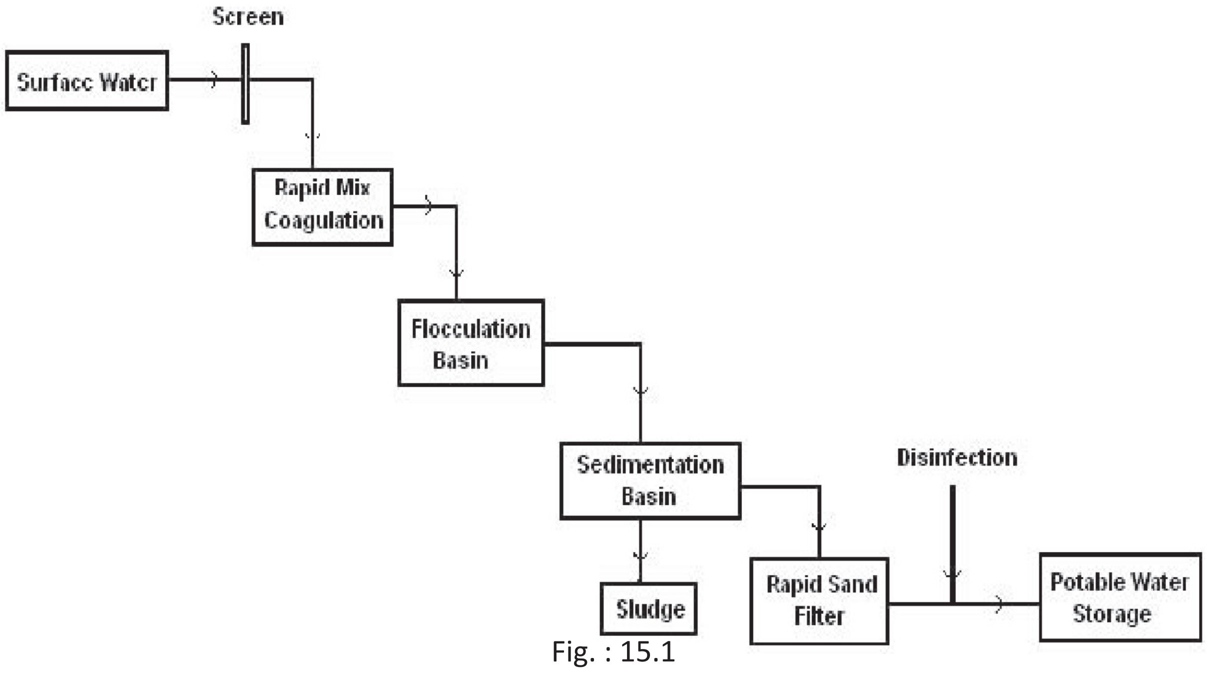


Fig. : 15.1

WASTEWATER TREATMENT PLANTS

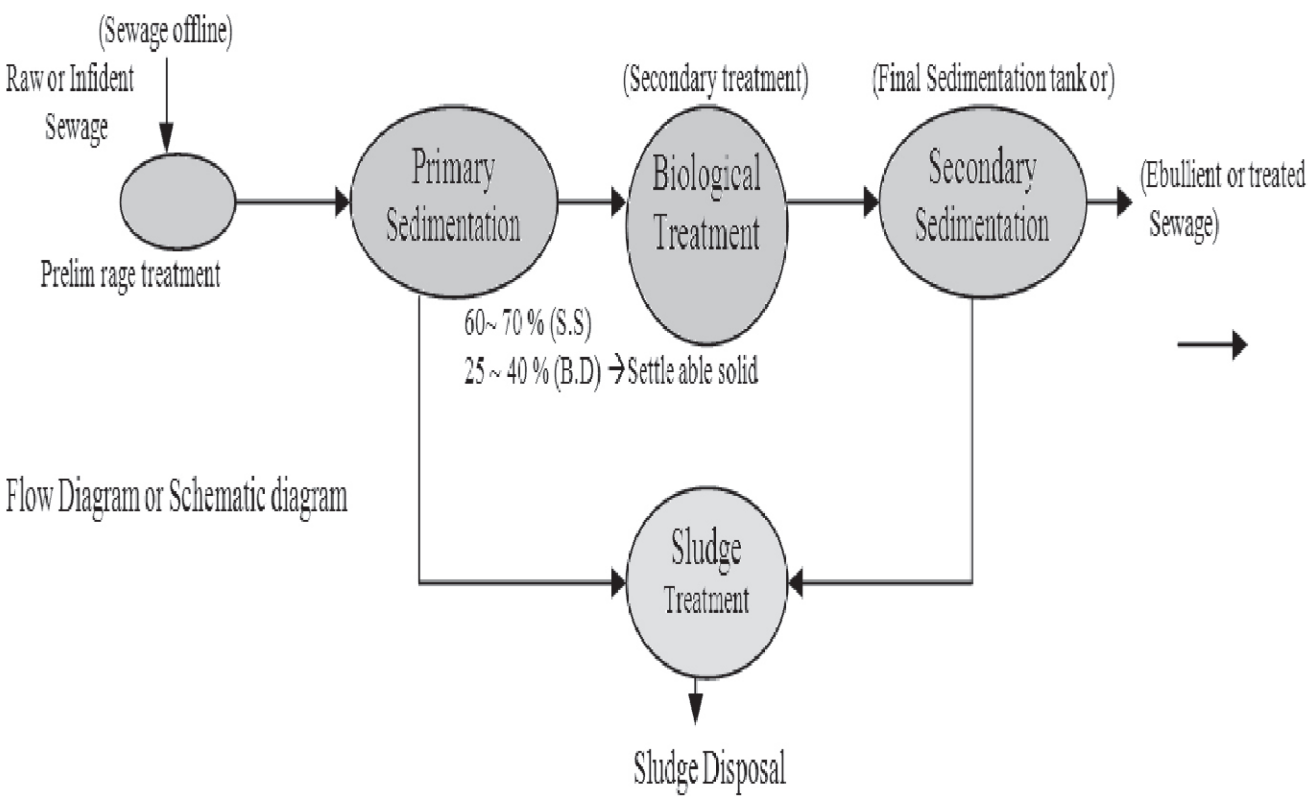


Fig. : 15.2

QUESTIONS

Chapter-1

1. Describe advantages and disadvantages offered by the water carriage system.
2. What are the possible adverse effects when untreated or partially treated sewage is discharged to the environment?
3. Why it is necessary to treat wastewater before disposal? What is the objective of the sewerage works?
4. Define sewage, sullage, sewer, and sewerage.

Chapter-2

1. What are the characteristics of Domestic Wastewater?
2. What are the characteristics of wastewater?
3. Give the types of solids found in water & wastewater? Explain it?

Chapter-3

1. What are the physical parameters in wastewater?Explain it?
2. What are the chemical parameters in wastewater? Explain it?
3. Explain the merits & demerits of effects of temperature in water?

Chapter-4

1. Define BOD & explain it?
2. Define COD & explain it?
3. How we can measure gross amount s of Organic matter in wastewater?

Chapter-5

1. What are the points to be considered while taking samples?
2. How sampling act as a "Tool for controlling of process of wastewater Treatment Plant?
3. Why sampling programs are undertaken?

Chapter-6

1. Write about evaluation of design discharge for sanitary sewage.
2. What is dry weather flow?
3. Describe variation in sewage flow. How design of different component of sewerage scheme will be affected due to this variation?
4. What is design period? It depends on what parameters? Provide design period for different components of the sewerage scheme.

Chapter-7

1. Which points should be considered while selecting materials for Sewer?
2. Why steel pipes are much better than CI pipes? Explain?
3. Give the merits & demerits of plain concrete cement & reinforced concrete cement?

Chapter-8

1. What is flow equalization? Mention types of equalization and how volume required for the equalization tank can be carried out?
2. Why flocculation is carried out in sewage treatment?
3. What is the need of tertiary treatment?

Chapter-9

1. Why aerobic treatment systems produce more sludge than anaerobic treatment systems?
2. Define SVI. calculate SVI of the sludge for the laboratory test results furnished below:
   sludge settled volume (SSV) after 30 min. settling = 280 ml
   MLVSS in aeration tank = 3500 mg/l, and ss/vss = 0.8
3. Why recycling of the sludge is necessary in activated sludge process?
4. What is sludge bulking? how it can be controlled?
5. Describe sequencing batch reactor.
6. Describe the working of moving bed biofilm reactor. what advantages this reactor will offer?

Chapter-10

1. What are the factors that determines the removal efficiency of Biodegradable Organic Matter?
2. What is UASB? Why post treatment is necessary in UASB?
3. Mention the merits of anaerobic decomposition process?

Chapter-11

1. What is RO? Explain?
2. What is DAF? Explain?
3. Mention the merits & demerits of Extended aeration & SBR?

Chapter-12

1. What is sludge? Explain types of sludge?
2. Mention the merits & demerits of aerobic & anaerobic digestion?
3. Describe the purpose of sludge thickening?

Chapter-13

1. What are the points to be considered for O & M of equalization tank?
2. What are the points to be considered for O & M of sedimentation tank?
3. What are the points to be considered for O & M of raw sewage lift pumps?

Chapter-14

1. Explain different types of water pollutants.
2. What are the adverse effects on the receiving water body when these pollutants are discharged in water along with effluents?
3. Describe thermal pollution. how it is caused?

Chapter-15

1. Describe sustainable sanitation?
2. In conventional sanitation, what are the factors that are most lethal to most of the pathogens?
3. Define health, hygiene & Environment?

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