ENVIRONMENTAL ENGINEERING

UNIT –I

Objective: i) To communicate the importance of supplying protected drinking water in maintaining public health.

ii) To discuss the basic premises of designing a water supply scheme to serve a community for a specific number of years.

iii) To assess the water demand for various uses including emergencies such as firefighting that have to be met by the water supply scheme.

iv) To identify the water quality norms and the laboratory procedures for testing the parameters.

Syllabus:
Waterborne diseases – protected water supply
Population forecast – design period
Water demand – factors affecting – fluctuations – fire demand – Storage capacity
Water quality testing – Drinking water standards as per IS: 10500 (2012)

Learning Outcomes: After learning this unit, the student will be able to

1. Name waterborne diseases and explain the precautions to avoid them.

2. Forecast population and suggest the design period of various components for serving a given area.

3. Break up water demand into various components and suggest the desired storage capacity of reservoir.

4. List the standards for drinking water and identify the desirable and permissible limits.

The meaning of waterborne diseases

The term "waterborne disease" is reserved largely for infections that predominantly are transmitted through contact with or consumption of infected water. **Waterborne diseases** are caused by pathogenic microorganisms that most commonly are transmitted in contaminated fresh water. Infection commonly results during bathing, washing, drinking, in the preparation of food, or the consumption of food that is infected. Various forms of waterborne diarrheal diseases probably are the most prominent examples, and affect mainly children in developing countries. Waterborne diseases are any illness caused by water that people drink after it is contaminated by animal or human feces, which contain pathogenic microorganisms.

Examples of waterborne diseases: Polio, Cholera, Scabies, Typhoid, Hepatitis, Diarrhea.

Disease	Bacteria
Cholera	Vibrio cholera
Botulism	Clostridium botulinum bacteria
Sore throat	Streptococcus bacteria
Whooping Cough	Bordetella pertussis
Dysentery	Shigella/Salmonella bacteria
Pneumonia	Streptococcus pneumoniae.
Leprosy	Mycobacterium lepromatosis
Typhoid	Salmonella typhi bacteria

Disease	virus
Severe Acute Respiratory Syndrome	Coronavirus
Hepatitis A	Hepatitis A virus
Poliomyelitis	Poliovirus

Disease	Protozoa
Amoebiasis	Entamoeba histolytica
Cryptosporidiosis	Cryptosporidium parvum
Cyclosporiasis	Cyclospora cayetanensis
Giardiasis	Giardia lamblia
Microsporidiosis	Microsporidia

Disease	Helminths
Hookworm disease	Ancylostoma duodenale or Necator americanus
Dracunculiasis	guinea worm, Dracunculus medinensis

Protected water supply:

Protected water supply means the supply of water that is treated to remove the impurities and made safe for human consumption. Water may be polluted by physical and bacterial agents. Water is also a good carrier of disease causing germs. Absolutely pure water is never found in nature (which contains only two parts of hydrogen and one part of oxygen by volume). But the water found in nature contains number of impurities in varying amounts. The rainwater which is originally pure also absorbs various gases, dust and other impurities while falling. This water when moves on the ground further carries silt, organic and inorganic impurities. The removal of the turbidity, odour and smell is considered as good and removal of dissolved substances is considered as “chemically pure”.

Requirements of protected water:

1. It should be free from bacteria
2. It should be colourless and sparkling
3. It should be tasty, odour free and cool
4. It should be free from objectionable matter

5. It should not corrode pipes
6. It should have dissolved oxygen and be free from carbonic acid so that it may remain fresh

Status of Protected Water Supply in India

Lack of safe drinking water in India is still a problem in many areas of the country. 88% of India's population is using improved drinking water sources. (Urban – 96%; Rural – 84%); however water delivered at the taps may not always be safe to drink
Source: World Health Statistics, 2011
India has more people in rural areas – 63.4 million – living without access to clean water than any other country, according to *Wild Water, State of the World's Water 2017,* new report by Water Aid, a global advocacy group on water and sanitation.
Only 26.9 million out of 167.8 million households (16%) in rural India have piped water, according to data provided by the ministry of drinking water and sanitation to the Rajya Sabha (upper house of Parliament) on February 6, 2017.

Design Period:

This water demand should be worked out with due provision for the estimated requirements of the future. The future period for which a provision is made in the water supply scheme is known as the design period.

Design period is estimated based on the following:

1. Useful life of the component, considering obsolescence, wear, tear, etc.
2. Expandability of the scope of the project.
3. Anticipated rate of growth of population, including industrial, commercial developments & migration-immigration.
4. Available resources.
5. Performance of the system during initial period.

Population forecast:

Forecasting population

To design a structure, sizing of the capacity of various components is required. As Water supply schemes are designed to serve population up to a number of years, we have to forecast population that needs to be served until the scheme is replaced by a new one in the distant future. The population of a particular area may increase. The cause of this increment may be

Development of new industries

If there are new big industries developed in an area, then population of that area is increased. Because people will migrate towards the industrial area to find employment opportunities.

Natural disasters

Natural disasters such as earthquake or flood in adjoining area may cause the population to migrate to safer areas.

Educational facilities

Increase in educational facilities in an area may cause population growth in that area.
Other reasons are

Increase in transport facilities

Political changes in adjoining countries

Factors that decrease the population may be deaths or migration from the city.
As increase in population is more than the decrease in population. So there is net increase in population.

Methods of forecasting population

The following are the standard methods for forecasting the population.

Mathematical methods

There are three mathematical methods to forecast population.

A. **Arithmetic method**

This method is based on the observation that the rate of population growth is constant. This method of forecasting population is used in those cities where population is more or less established.

It can be expressed as

Rate of population growth = constant

$P_2 - P_1 = C\ (t_2 - t_1)$

P_1 = Population at the time t_1

P_2 = Population at the time t_2

The value of constant C is determined

The population after n decades is determined by the formula

$$P_n = P + n.C$$

B. **Geometric method**

Geometric method of forecasting population is based on the hypothesis that the rate of growth of a particular area is proportional to the population.

This method is used for the region where population is growing rapidly.

If the present population is P and the average percentage growth is I_G the population at the end of n decades will be

$$P_n = P\ (1 + I_G/100)^n$$

C. **Incremental increase method**

This method is an improvement over the above two methods.

P is present population, Ia = avg. arthimetical increase, and Ic = avg. incremental increase then the population after n decades will be

$$Pn = P + n\ (Ia + Ic)$$

D. **Decreasing rate method**

In this method the average decrease in the percentage increase is worked out and is then subtracted from the latest percentage increase for each successive decade.

Curvilinear or graphical methods

These methods of forecasting population involve the graphical projection of the past population growth curve.

The commonly used graphical methods are

A. **Using population of the city**

In this method the procedure is as follows.

1. Plot the population data such as time in years in x-axis and population data on y-axis.
2. Join all the points and make the curve of the given data considering various factors.
3. Extend the curve considering various factors and find out the population at required future year,
4. If the curve is properly extended keeping all the factors in view, this method may result better than that of mathematical methods.

B. **By ratio method**

It is based on the hypothesis that the population growth of a city has a relationship to the population of the whole country. The change rate of population of the city is the same as that of the country.

C. **Comparision with other similar cities**

In this method, care should be taken that the cities selected for comparison should be as similar as possible to the city under consideration. The cities selected for comparision should have already attained the expected future population of the city.

Water demand:

Six types of water demands to be considered while designing water supply scheme

When designing the water supply project for a town or city, it is essential to determine the detailed quantity of water required for various purposes by the city. But as there are so many aspects involved in demand of water, it is impossible to precisely figure out the actual demand. Certain empirical formula and rules of thumb are used in determining the water demand, which is very near to the real demand.

Following are the various types of water demands of a city or town:

1. Domestic Water Demand

The amount of water necessary in the residences for drinking, bathing, cooking, washing etc is known as domestic water demand and primarily depends on the habits, social status, weather and traditions of the people. The domestic consumption of water in India is about 135 litres/day/capita. But in developed countries this figure may be 325 - 340 litres /day/capita because of use of air coolers, air conditioners, maintenance of lawns, automatic household appliances etc.,

2. Industrial Demand

The water needed in the industries mostly relies on the kind of industries that are established within the town. The water needed by various industries like Paper mills, Cloth mills, Cotton mills, Breweries, Sugar Mill etc. comes under industrial use. About 20 – 25% of total water demand of an industrial town is normally considered as industrial water demand.

3. Institution and Commercial Demand

This type of water demand includes the water requirement for the public buildings other than residences. Commercial buildings, Malls, Colleges, Hotels, Bus depots and other similar public buildings comes within this category.

4. Water demand for Public Use

Volume of water necessary for public utility needs like for washing and sprinkling on roads, cleaning of sewers, watering of public parks, gardens, public fountains etc., comes under public demand. Usually 5 % of total water demand for city is considered for public use while designing water supply scheme.

5. Fire Demand

Water requirement for firefighting purpose falls under this head. The volume of water necessary for firefighting is usually computed by making use of various empirical formulae. The quantity of water required for firefighting is generally calculated by using the following empirical formulae

4. National board of fire under writers formula

   $Q = 4640 \sqrt{p} (1 - 0.01 \sqrt{p})$

   Q = Quantity of water required in lit/min

   p = population of the town in thousands.

4. Freeman formula

   Q = 1135.5 (P/5 + 10) in lit/min

   P = Period of occurrence of fire in years

4. Kuchlings formula

   Q = 3182 √P

   Q = Volume of water required in Lits / Hour

   P = Population of city in thousands

6. Wastage and losses

There are always losses and wastage occurs in pipeline during water distribution. The main reasons for this are listed below

1. Damaged pipe line and or faulty accessories like valves, fittings etc.
2. Water taps kept open in public or residences causing water wastage
3. Due to illegal and unauthorized connections

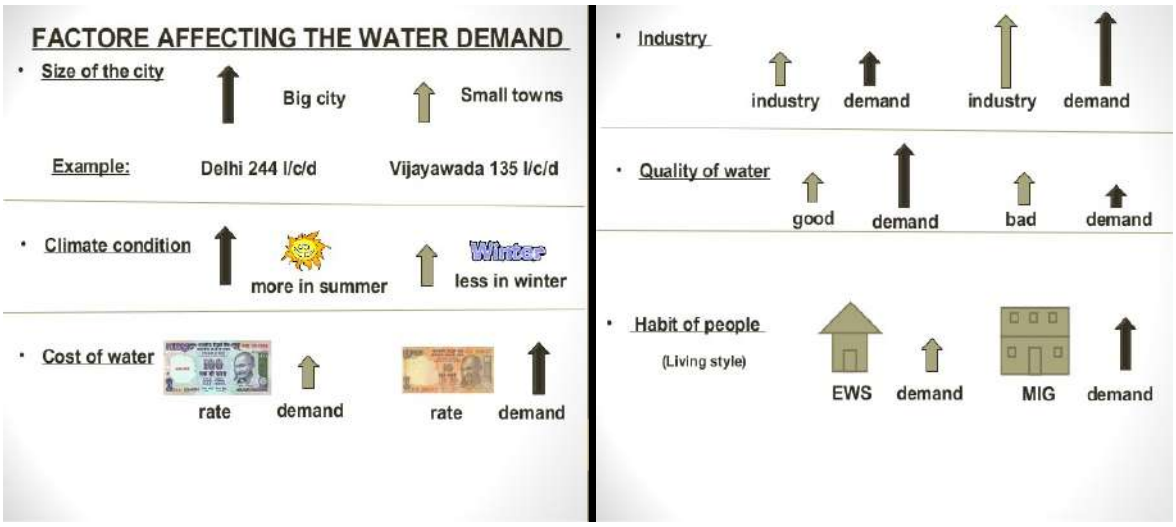
While calculating the total amount of water of a town; allowance of 12- 15% of water is designed to make up for losses, thefts and wastage of water.

Factors effecting water demand:

Following are main factors which affect the per capita demand of the city:

4. Climatic conditions
4. Size of the community
4. Living standard of the people

(d) Industrial and commercial activities
(e) Pressure in the distribution system
(f) System of sanitation
(g) Cost of water



Fluctuation in water demand:

Demand of water does not remain uniform throughout the year but it varies from season to season, even from hour to hour.

Types of fluctuation:

1. Seasonal fluctuation
2. Daily and hourly fluctuation

Storage capacity of reservoir:

The capacity of the storage reservoir depends on the rates of inflow, losses and demand or out flow. For determining the capacity of the storage reservoir to be constructed, it has to be determined first. The inflow and out flow values are to be determined for various months of the years. The deficits and surpluses of water are calculated, and the storage capacity is made equal to the deficit. For remaining on the safer side, the dry year in which the inflow was maximum and the outflow was maximum is generally chosen for this purpose.

Water quality: Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, and drinking water.

The series of IS codes that explain the test procedures can be downloaded at

https://law.resource.org/pub/in/bis/manifest.chd.32.html

Some of the parameters are explained here below.

Water Quality Tests (IS3025):

Dissolved Oxygen

This test is the most important of the nine water quality tests to measure water's ability to support plants and animals. There are many different factors that affect the amount of dissolved oxygen in water, the main one being temperature. As temperature rises, less gas will dissolve.

Collect the sample in a glass stoppered bottle of 500 ml capacity. Add 10 ml of alum solution followed by 2 ml of ammonium hydroxide, mix the contents gently by inverting the bottle and allowing to settle for 15 minutes. Collect the supernatant liquid into 300 ml dissolved oxygen bottle. Avoid aeration and keep the siphon sufficiently submerged during transfer.

The dissolved oxygen in mg / litre is equal to the volume in ml of the standard thiosulphate solution used for titration.

Turbidity

Turbidity measures water clarity, which allows sunlight to penetrate to a greater depth. The main sources of turbidity are erosion, living organisms, and those from human endeavors.

Turbidity less Than 43 Units: Shake the sample to disperse the solids. Wait until air bubbles disappear. Pour sample into turbidimeter tube and read turbidity directly from the instrument scale or from calibration curve.

Turbidity greater than 40 Units: In case turbidity values are greater than 40 units, dilute the sample with turbidity-free water to bring the values within range. Take readings of diluted sample. Compute the turbidity of the original sample from the turbidity of the diluted sample and the dilution factor.

Total Solids

Total solids measures both dissolved and suspended solids. There are six major types of total solids; silt, clay, soil runoff, plankton, industrial waste, and sewage.

1. Heat the clean evaporating dish to 180°C for 1 hour. Cool, desiccate, weigh and store in desiccators until ready for use.
2. Select volume of the sample which has residue between 25 and 250 mg, preferably between 100 and 200 mg. This volume may be estimated from values of specific conductance. To obtain a measurable residue; successive aliquots of sample may be added to the sample dish.
3. Pipette this volume to a weighed evaporating dish placed on a steam-bath. Evaporation may also be performed in a drying oven. The temperature should be lowered to approximately 98°C to prevent boiling and splattering of the sample. After complete evaporation of water from the residue, transfer the dish to an oven at 103-105°C, or 179-181°C and dry to constant mass, that is, till the difference in the successive weighings is less than 0.5 mg. Dry for a long

duration (usually 1 to 2 hours) is done to eliminate necessity of checking for constant mass. The time for drying to constant mass with a given type of sample when a number of samples of nearly same type are to be analyzed should be determined by trial.
4. Weigh the dish as soon as it has cooled avoiding residue to stay for long time as some residues are hygroscopic and may absorb water from desiccant which may not be absolutely dry.

pH Level
The pH of water is important to aquatic life. If the pH falls below 4 or above 9 everything is dead.
After required warm-tip period, standardize the instrument with a buffer solution of pH near that of the sample and check electrode against at least one additional buffer of different pH value. Measure the temperature of the water and if temperature compensation is available in the instruments adjust it accordingly. Rinse and gently wipe the electrodes with solution. If field measurements are being made, the electrodes may be immersed directly in the sample stream to an adequate depth and moved in a manner to ensure sufficient sample movement across the electrode sensing element as indicated by drift free readings. If necessary, immerse them into the sample beaker or sample stream and stir at a constant rate to provide homogeneity and suspension of solids. Rate of stirring should minimize the air transfer rate at the air-water interface of the sample. Note and record sample pH and temperature However, if there is a continuous drift, take a second reading with the fresh aliquot of sample without stirring and report it as the pH value.
Temperature and Flow Rate
Temperature is a very important part of a river's ecology. There are many natural and human factors that can affect a river's temperature. Human factors include industry, development, and dams. To measure temperature and flow rate you must find two places along the river that are about 1.6 km apart that have the same conditions, then two people measure the temperature at approximately the same time. If the difference is greater than 2 degrees Celsius, then there is thermal pollution.
Nitrates
Nitrogen is necessary for plant and animal life. Water is tested for nitrates to monitor and control eutrphication, which causes more plant growth and decay.
Biochemical Oxygen Demand
BOD is a measure of oxygen removed from an aquatic environment by aerobic microorganisms. It measures levels of organic pollution in lakes and streams.
Phosphorous
Phosphate is a nutrient needed in growth. The phosphate ion is found in shells, bones, and in animal teeth. By removing phosphorous from sewage the amount of phosphate ions in the water will be lowered.

Drinking water standards as per IS 10500: 2012

Physical parameters

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to Part of IS 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Colour, Hazen units, *Max*	5	15	Part 4	Extended to 15 only, if toxic substances are not suspected in absence of alternate sources
ii)	Odour	Agreeable	Agreeable	Part 5	a) Test cold and when heated b) Test at several dilutions
iii)	*p*H value	6.5-8.5	No relaxation	Part 11	—
iv)	Taste	Agreeable	Agreeable	Parts 7 and 8	Test to be conducted only after safety has been established
v)	Turbidity, NTU, *Max*	1	5	Part 10	—
vi)	Total dissolved solids, mg/l, *Max*	500	2 000	Part 16	—

NOTE — It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Bacteriological Quality of Drinking Water

Sl No.	Organisms	Requirements
(1)	(2)	(3)
i)	*All water intended for drinking:*	
	a) *E. coli* or thermotolerant coliform bacteria[2), 3)]	Shall not be detectable in any 100 ml sample
ii)	*Treated water entering the distribution system:*	
	a) *E. coli* or thermotolerant coliform bacteria[2)]	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample
iii)	*Treated water in the distribution system:*	
	a) *E. coli* or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample

General Parameters Concerning Substances Undesirable in Excessive Amounts

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Aluminium (as Al), mg/l, *Max*	0.03	0.2	IS 3025 (Part 55)	—
ii)	Ammonia (as total ammonia-N), mg/l, *Max*	0.5	No relaxation	IS 3025 (Part 34)	—
iii)	Anionic detergents (as MBAS) mg/l, *Max*	0.2	1.0	Annex K of IS 13428	—
iv)	Barium (as Ba), mg/l, *Max*	0.7	No relaxation	Annex F of IS 13428* or IS 15302	—
v)	Boron (as B), mg/l, *Max*	0.5	1.0	IS 3025 (Part 57)	—
vi)	Calcium (as Ca), mg/l, *Max*	75	200	IS 3025 (Part 40)	—
vii)	Chloramines (as Cl_2), mg/l, *Max*	4.0	No relaxation	IS 3025 (Part 26)* or APHA 4500-Cl G	—
viii)	Chloride (as Cl), mg/l, *Max*	250	1 000	IS 3025 (Part 32)	—
ix)	Copper (as Cu), mg/l, *Max*	0.05	1.5	IS 3025 (Part 42)	—
x)	Fluoride (as F) mg/l, *Max*	1.0	1.5	IS 3025 (Part 60)	—
xi)	Free residual chlorine, mg/l, *Min*	0.2	1	IS 3025 (Part 26)	To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be minimum 0.5 mg/l
xii)	Iron (as Fe), mg/l, *Max*	0.3	No relaxation	IS 3025 (Part 53)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xiii)	Magnesium (as Mg), mg/l, *Max*	30	100	IS 3025 (Part 46)	—
xiv)	Manganese (as Mn), mg/l, *Max*	0.1	0.3	IS 3025 (Part 59)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xv)	Mineral oil, mg/l, *Max*	0.5	No relaxation	Clause 6 of IS 3025 (Part 39) Infrared partition method	—
xvi)	Nitrate (as NO_3), mg/l, *Max*	45	No relaxation	IS 3025 (Part 34)	—
xvii)	Phenolic compounds (as C_6H_5OH), mg/l, *Max*	0.001	0.002	IS 3025 (Part 43)	—
xviii)	Selenium (as Se), mg/l, *Max*	0.01	No relaxation	IS 3025 (Part 56) or IS 15303*	—
xix)	Silver (as Ag), mg/l, *Max*	0.1	No relaxation	Annex J of IS 13428	—
xx)	Sulphate (as SO_4) mg/l, *Max*	200	400	IS 3025 (Part 24)	May be extended to 400 provided that Magnesium does not exceed 30
xxi)	Sulphide (as H_2S), mg/l, *Max*	0.05	No relaxation	IS 3025 (Part 29)	—
xxii)	Total alkalinity as calcium carbonate, mg/l, *Max*	200	600	IS 3025 (Part 23)	—
xxiii)	Total hardness (as $CaCO_3$), mg/l, *Max*	200	600	IS 3025 (Part 21)	—
xxiv)	Zinc (as Zn), mg/l, *Max*	5	15	IS 3025 (Part 49)	—

UNIT – II

Syllabus: Intakes, Infiltration galleries; Distribution systems - Requirements, Methods and layouts; Hardy Cross and Equivalent Pipe methods; Capacity by mass curve method; Types of joints, valves and water meters; Layout and general outline of water treatment units; Sedimentation - Principles and design factors, Coagulation - flocculation

Objectives: i) To introduce various engineering structures involved in the conveyance of raw water from source to treatment plant site.
ii) To apprise and analyse suitable water supply distribution system and layout for a particular serviced area.
iii) To make aware the concepts involved and elaborate the methods for analysis of complex pipe networks for designing a distribution system pipe network.
iv) To calculate the service reservoir capacity for equalising the demand and supply of water using various methods.
v) To list and recommend various joints, valves, meters for use in potable water distribution
vi) To draw flowchart / schematic / label various unit operations and processes that form the water treatment plant.
vii) To understand basic principles and methods of water treatment such as sedimentation, coagulation and flocculation.

Learning Outcomes: After completing this unit, the student will able to

1. Illustrate the water supply scheme as a schematic and explain the logic and sequence of various unit processes and operations.

2. Identify different options for collection and conveyance structures for raw water.

3. List and recommend suitable distribution systems, layouts and analysis methods for design of complex pipe networks.

4. Explain and recommend various types of joints, valves and water meters for use in a water supply distribution network.

5. Explain the theoretical basis for various treatment processes such as Sedimentation, coagulation and flocculation.

6. Solve problems related to designing capacity of reservoir, sedimentation tank,

coagulation and flocculation tank.

Intakes:

The main function of intake works is to collect the water from the surface source and then discharge the water so collected, by means of pumps or directly to the water treatment plants.

The following points should be kept in mind while selecting a site for intake works.

1. At the site, there should not be heavy current of water which might endanger the safety of the intake works.

2. The site of intake should be easily approachable without any obstruction.

3. As far as possible the selection of the site should be near the treatment works, it will reduce the conveyance cost from the source to the waterworks.

4. The site should not be located in navigation channels, because such water is polluted and contains toilet and other discharges from the vessels.

5. As far as possible the intake should not be located in the vicinity of the point of sewage disposal.

6. The site should be such that intake work can draw more quantity of water if required in future i.e., there should be sufficient scope for future enhancement.

Types of Intakes

Intakes are used to collect water for water works from various sources. The sources may be rivers, reservoirs or canals. The intake work for each type of source is designed separately according to its requirements and situations. Depending on the source of water the intake works are classified as follows.

(a) Lake Intake
(b) Reservoir Intake
(c) River Intake
(d) Canal Intake

(a) Lake Intake:

1. For obtaining water from lakes mostly submersible intakes are used.

2. Fig shows typical submersible type of intake used for collecting water from the lakes.

Intakes are constructed in the bed of the lake below the slow water level so as to draw water in dry season also.

1. It essentially consists of a pipe laid in the bed of the lake. One end, which is in the middle of the lake, is fitted with bell mouth opening covered with a mesh and protected by timber or concrete crib.

2. The water enters in the pipe through the bell mouth opening and flows under gravity to the bank where it is collected in a sump-well and then pumped to the treatment plants for necessary treatment.

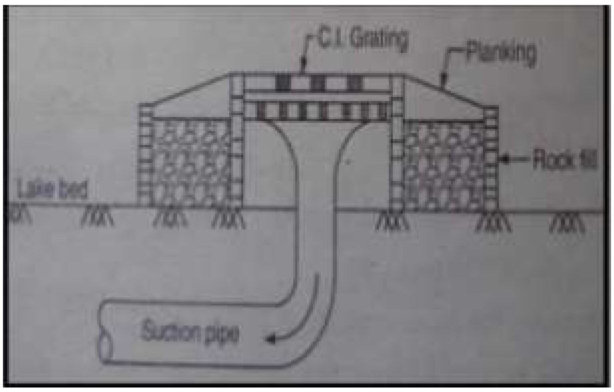


Fig 1: Lake Intake

(b) Reservoir Intake:

1. Figure shows a reservoir intake which is mostly used to draw the water from earthen dam reservoir.

2. It essentially consists of an intake tower constructed on the slope of the dam at such place from where intake can draw sufficient quantity of water even in the driest period.

3. Intake pipes are fixed at different levels, so as to draw water near the surface in all variations of water level. These all inlet pipes are connected to one vertical pipe inside the intake well.

4. Screens are provided at the mouth of all intake pipes to prevent the entering of floating and suspended matter in them. The water which enters the vertical pipe is taken to the other side of the dam by means of an outlet pipe.

5. At the top of the intake lower sluice valves are provided to control the flow of water.

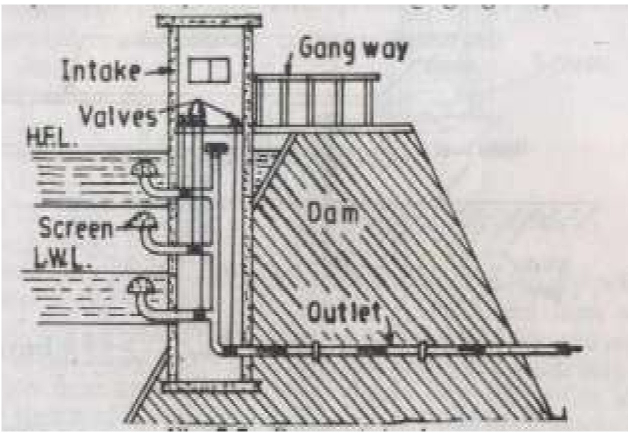


Fig 2: Reservoir Intake

(c) River Intake:

6. There is a large variation in discharge of all the rivers during monsoon and summer.

1. Figure shows a typical intake used to draw water from the rivers. It is a circular masonry tower of 4 to 7 metres in diameter constructed along the bank of the river at such place from where required quantity of water can be obtained even in the dry period.

2. The water enters in the lower portion of the intake known as sump-well from penstocks. The penstocks are fitted with screens to check the entry of floating solids and are placed on the downstream side so that water free from most of the suspended solids may only enter the jack-well.

3. Number of penstock openings are provided in the intake tower to admit water

at different levels. The opening and closing of penstock valves is done with the help of wheels provided at the pump-house.

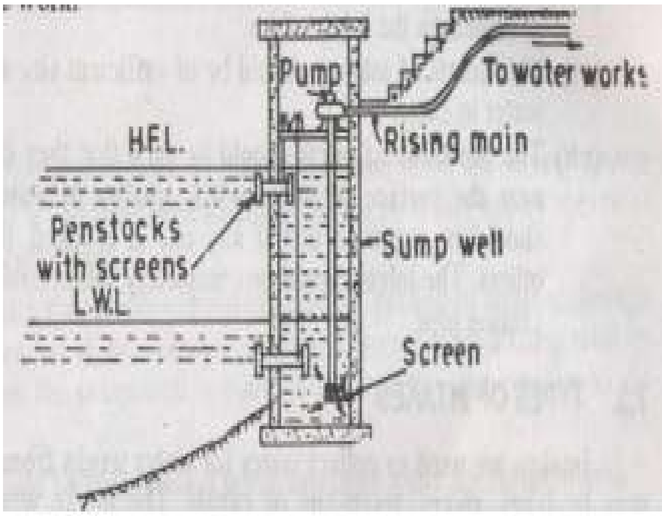


Fig 3: River Intake

Infiltration Galleries: Ground water travels towards lakes, rivers and streams. This water which is travelling can be intercepted by digging a trench or by constructing a tunnel with holes on sides at right angle to the direction of flow of ground water.

These underground tunnel used for tapping underground water near rivers, lakes and streams are called Infiltration Galleries. Underground water may b e allowed to enter these infiltration galleries from both side or one side as desired. Sometimes these are known as horizontal wells.

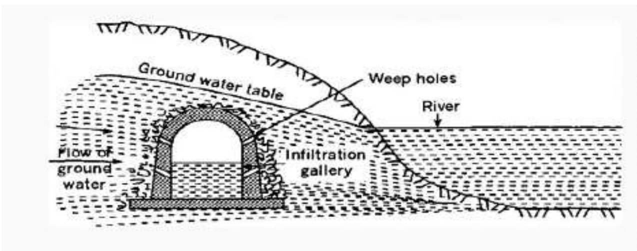


Fig 4: Infiltration Galleries

Distribution Systems:

Distribution system is a network of pipelines that distribute water to the consumers. They are designed to adequately satisfy the water requirement for a combination of

1. Domestic

2. Commercial
3. Industrial
4. Fire fighting purposes

The distribution system consists of pipes of various sizes, valves, meters, pumps, distribution reservoirs, hydrants, stand posts etc,. The pipe lines carry the water to each and every street, road. Valves control the flow of water through the pipes. Meters are provided to measure the quantity of water consumed by individual as well as by the town.

Depending upon the methods of distribution, the distribution systems are classified as follows

1. Gravity system
2. Pumping system
3. Combined gravity and pumping system

Requirements of a good distribution system:

1. It should convey the treated water up to the consumers with the same degree of purity.
2. The water should reach to every consumer with the required pressure.
3. The distribution system should be economical and easy to maintain and operate.
4. It should be able to transport sufficient quantity of water during emergency such as fire fighting.
5. During repair work, it should not cause obstruction to the traffic.
6. It should be safe against any future pollution.
7. It should be water tight and the water losses due to leakage should be minimum as far as possible.

Layouts of distribution systems:

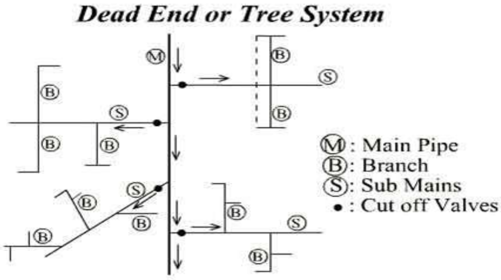
Generally in practice there are four systems of distribution which are used. Depending upon their layout and direction of supply, they are classified as follows:

1. Dead end or Tree system
2. Grid iron system
3. Circular or ring system
4. Radial system

1. Dead end or Tree system:

It is the system in which each street or block is supplied separately from the main. So there is end of system at each end of the block.

Dead End or Tree System



Advantages

1. This type of system is good for a city which has been developed haphazardly.
2. As it required less number of valves so it is economical.
3. This type of system is easy to construct.

Disadvantages

This system is less desirable due to following reasons

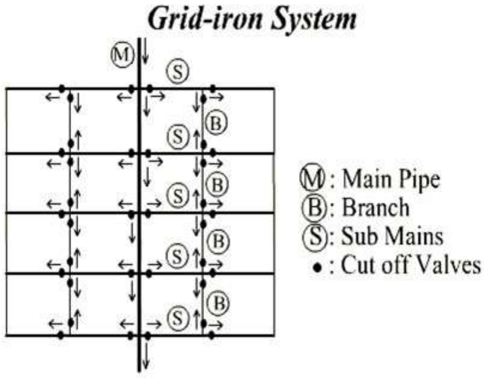
1. Large areas are cut off during repairing.

2. When tap is not opened for a long time, bacterial growth may take place.

3. The dead ends accumulate settled sediments which reach the consumer.

2. Grid iron system

In grid iron system, the whole distribution system is interconnected. So the water remains in circulation and there is no contamination of water. Because water does not stand still at any point, it is in continuous circulation.



Advantages

1. In this system, as the whole distribution system is interconnected, water can reach from more than one direction.

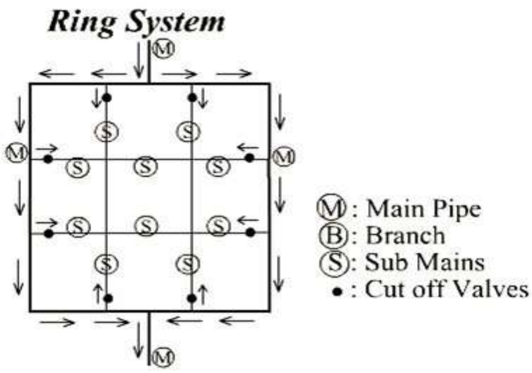
2. It provides better quality of water.

3. During its repairing lesser area is cut off.

c. Circular or ring system

Circular or ring system can be adopted in well planned locality of cities.

1. Each locality is divided into square or circular blocks and water mains are laid all around four sides or round the circle.
2. This is the best of other systems but it requires many more valves and pipes. Design is easy.

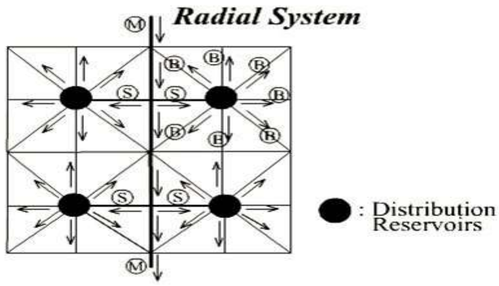


The advantages and disadvantages of this system are same as that of grid iron system.

d. Radial system

1. Not opted in India because for this system the roads should be laid out radially from a centre.
2. It is reverse of ring system water flows towards outer periphery from one point.
3. The entire district is divided into various zones and one reservoir is provided

for each one.



Methods of supplying water:

The water can be supplied to the consumers by the following two systems

1. **Continuous system**: This is the best system and the water is supplied for all the twenty four hours. This system is possible when there is adequate quantity of water for supply. In this system ample water is always available for the fire fighting and due to continuous circulation water always remains fresh.
2. **Intermittent system**: If plenty of water is not available, the supply of water is divided into zones and each zone is supplied with water for fixed hours in a day. As the water is supplied after intervals, it is called intermittent system. In spite of number of disadvantages, this system is usually adopted in almost all of cities and towns of India.

Analysis of Complex Pipe Networks:
Hardy-Cross Method

In this method, the corrections are applied to the assumed flow in each successive trial. The head loss in each pipe is determined by pipe flow formula. The successive corrections are made in the flows in each pipe until the heads are balanced and the principle of continuity is satisfied at each junction.

Now if Q_a be the assumed flow in pipe and Q be the actual flow in that pipe, then correction will be given by the equation

$$\Delta = Q - Q_a$$

$$Q = Q_a + \Delta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

If the head loss in the pipe under reference is H_L, it can be determined by the formula

$H_L = k \, . \, Q_a$ (k is a constant depending upon the size of the pipe)

The head loss can also be determined by Hazen-William's formula,

$$H_L = k.\, Q^{1.85}$$

Now putting $Q = Q_a + \Delta$ from (1)

$$H_L = k\,(Q_a + \Delta)^x$$

$$= k\,(Q^x_a + x\,Q^{x-1}\,\Delta)$$

......................neglecting terms containing higher power of Δ

In the closed network of a pipe line, the total loss of head must be zero

$$\sum k\,(Q^x_a + x\,Q^{x-1}\,\Delta) = 0$$

$$\sum (k\,Q^x_a) = -\sum (kQ^{x-1}\,x\,\Delta)$$

The Δ (very small value) can be taken out from summation

$$\sum (k\,Q^x_a) = -\Delta \sum (kQ^{x-1}\,x)$$

$$\Delta = -\left(\sum (k\,Q^x_a) / \sum (kQ^{x-1}\,x)\right)$$

$$= -\sum H_L / x \sum (H_L / Q_a)$$

The value of x is taken 1.85 (as per Hazen Williams formula) in this method known as *Hardy cross method.*

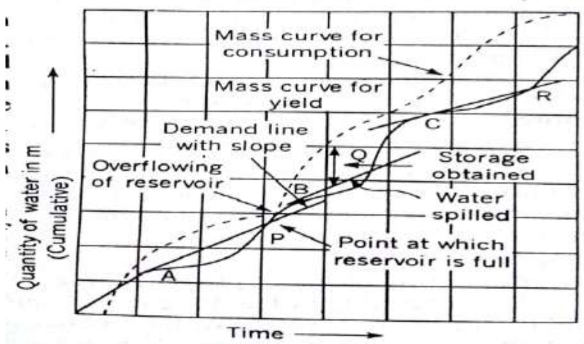
Equivalent pipe method:

This method is sometimes used as an aid in solving large networks of pipes in which it becomes convenient to, first of all, replace the different small loops by single equivalent pipes having the same head loss.

In this method, pipe circuit can be reduced into a single equivalent pipe of using the following two principles of hydraulics:

1. The loss of head caused by a given flow of water through the pipes connected in series, is additive.
2. The quantity of discharge flowing through the different pipes connected in parallel will be such as to cause equal head loss through each pipe.

Capacity by mass curve method:



The mass curve or consumption and yield can be used to determine the reservoir storage capacity. Figure above shows the mass curve of consumption and yield. The demand lines drawn tangent to the high point A.B.C........ of the mass curve, represent the rate of withdrawal from the reservoir. Point P, Q, R at which the demand line intersecting the mass curve of consumption denotes the points, at which the reservoir is full.

The vertical distance at any point between the demand line and the mass curve of consumption, denotes the water wasted over the spillway. The design of the spillway should be done such that, it should be sufficient to discharge the flood water.

When the total yield is more than the total consumption, the mass curve of yield remains above the mass curve of consumption and vice versa. The storage capacity or the requirement in dry weather will be found by adding maximum ordinates of loops in the adjoining deficit and excess periods. If the cumulative quantity of water yield is continuously in excess, both the mass both curves interact each other, which denotes that before this point the yield was less than the estimated consumption. For this period necessary provision or water is to be made. The same principle can be used for designing the balancing capacity of a reservoir as well.

Joints:

Various types of joints which are mostly used are as

1. Spigot and socket joint 5. Flexible joint
2. Expansion joint 6. Screwed joint
3. Flanged joint 7. Collar joint

4. Mechanical joint 8. A.C. pipe joint

1. Spigot and socket joint

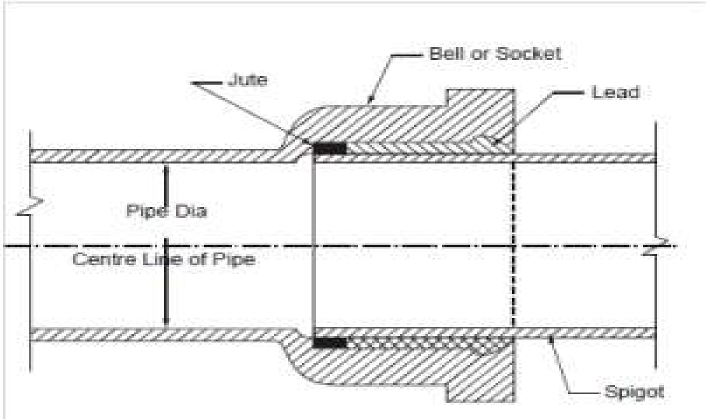


Fig: Spigot and socket joint

Sometimes this is called bell and spigot joint. This type of joint is mostly used for iron pipes. For the construction of this joint the spigot or normal end of pipe is slipped in socket or bell end of the other pipe until contact is made at the base of the bell. After this yarn of hemp is wrapped around the spigot end of the pipe and is slightly filled in the joint by means of yarning iron up to 5 cm depth. After packing of hemp a gasket or joint runner is clamped in place round the joint. Sometimes wet clay is used to make tight contact between runner and the pipe so that hot lead may not run out of joint space. The molten lead is then poured into the V shaped opening left in the top by the clamped joint runner. The space between the hemp yarn and the clamp runner is filled with molten lead.

The quantity of lead required per joint varies from 3.5 to 4 kg for 15 cm dia. pipe, to about 45-50 kg for 120 cm dia. pipe. Now a days some times to reduce the cost of filling lead , certain patented compounds of sulphur and other materials are filled in the joints, but these do not provided flexibility equal to that of lead.

2. Expansion joint

This joint is used at such places where pipes expand or contract due to change in atmospheric temperature and thus check the setting of thermal stresses in the pipes. In this joint the socket end is flanged with cast iron follower ring, which can freely slide on the spigot end or lane end of other pipe an elastic rubber gasket is tightly pressed between the annular space of socket and spigot by means of bolts. In the beginning while fixing the follower ring some space is left between the socket base and spigot end for the free movement of the pipes. The elastic rubber gasket in every position keeps the joint water tight.

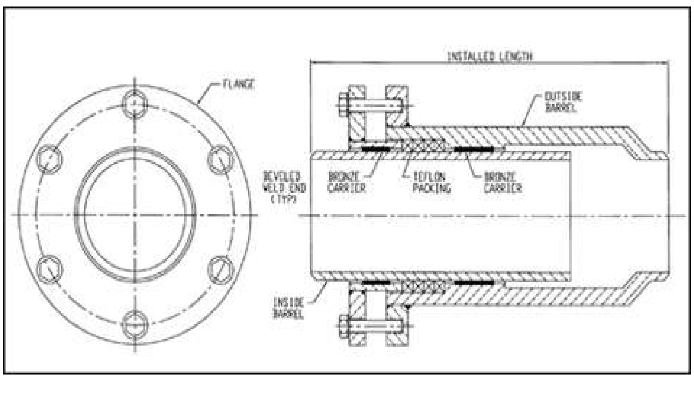


Fig: Expansion joint

3. Flanged joint

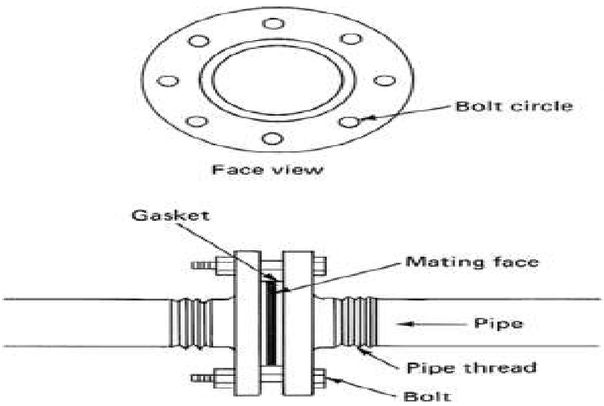


Fig: Flanged joint

This joint is mostly used for temporary pipelines, because the pipe line can be dismantled and again assembled at other place. The pipe in this case has flanges on its both ends, cast, welded or screwed with the pipe. The two ends of the pipe are brought in perfect level near one another and after placing one hard rubber washer between flanges are bolted. This joint can be used at such places where it has to bear vibrations or deflection of pipes etc.

4. Mechanical joint

This type of joint is used for jointing cast iron, steel pipes. There are two types of mechanical joints.

1. **Dresser couplings:** It essentially consists of one middle ring, two follower rings and two rubber gaskets. The two follower rings are connected together by bolts, and when they are tightened, they press both the gaskets tightly below the ends of the middle ring. These are very strong and rigid and can withstand vibrations up to certain limit.
2. **Victaulic joint:** In this type a gasket or leak proof ring is slipped over the both ends. This gasket is pressed from all sides on both the pipes by means of half iron couplings by bolts. This joint can bear shocks, vibrations and is used for cast iron and steel pipes.

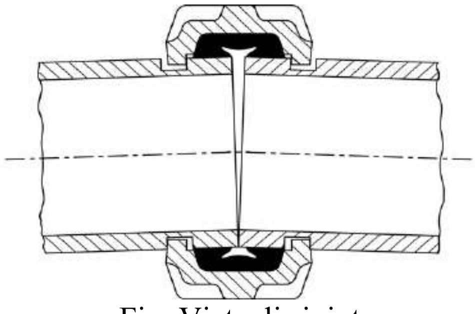
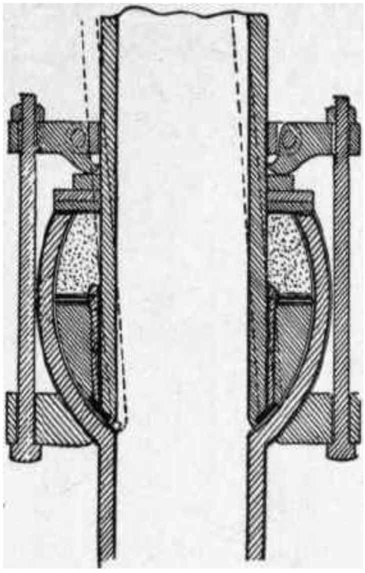


Fig: Victaulic joint

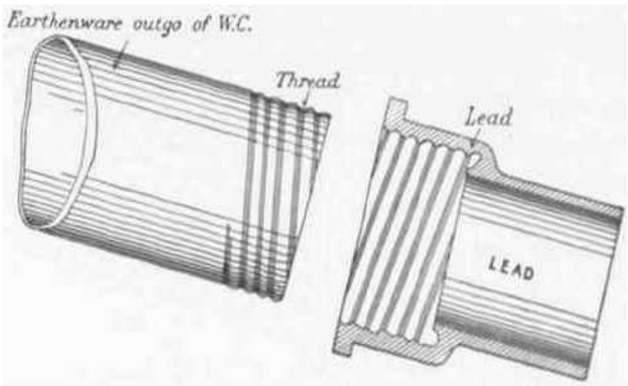
5. Flexible joint

Sometimes this joint is also called bell and socket joint or universal joint. This joint is used at such places where settlement is likely to occur after laying the pipe lines and used for laying pipes on curves. The cast end is in a spherical shape. The spigot end is plain but has a bead at the end. The spigot end of the pipe is kept in the spherical end of the other pipe. After this retainer ring is slipped which is stretched over the bead. Then a rubber gasket is moved which touches the retainer high. After it split cast iron gland ring is placed, the outer surface of which has the same shape as inner surface of the socket end. Over this finally cast iron follower ring is moved and is fixed to the socket end by means of bolts.



6. **Screwed joint**

This joint is mostly used for connecting small diameter cast iron and galvanized pipes. The ends of the pipes have threads on outside, while socket has threads on the inner side. The same socket is screwed on both ends of the pipes to join them. For making water tight joint zinc paint or hemp yarn should be placed in the threads of the pipes, before screwing socket over it.



7. **Collar joint**

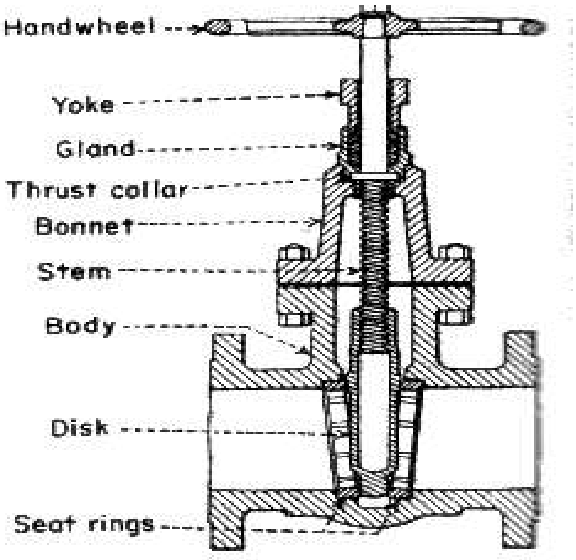
This joint is mostly used for joining big diameter concrete and asbestos cement pipes. The ends of two pipes are brought in one level before each other. Then rubber gasket between steel rings or jute rope soaked in cement is kept in the grove and the collar is placed at the joint so that it should have the same lap on the both sides. Now cement mortar is filled in the space between the pipes.

Valves:

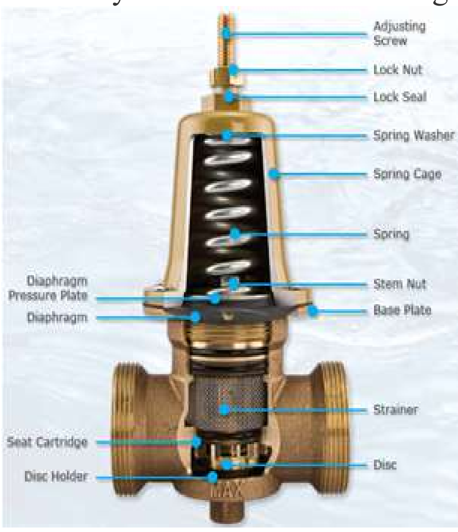
In water work practise, to control the flow of water, to regulate the pressure, to release or to admit air, to prevent flow of water in opposite direction and for so many purposes, valves are required.

1. **Sluice valve:**

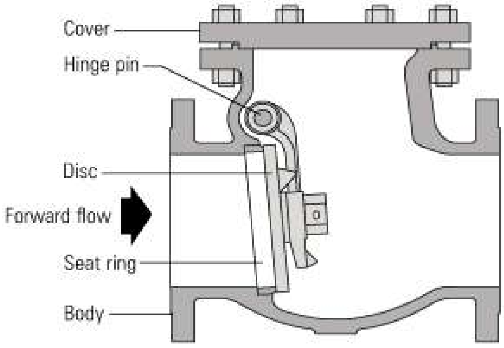
These are also known as gate valves and most commonly used water work practise.
Gate valve is full way valve which is inserted into a pipeline for controlling or stopping the flow of water. This valve offers low resistance to the flow of water. The valve is closed by turning hand wheel into clock wise direction. Nominal sizes of valves are 15 mm to 100 mm.



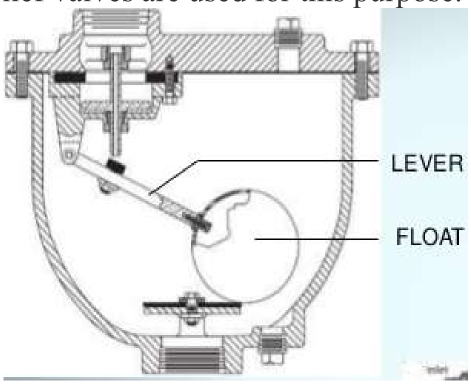
2. **Pressure relief valves**
   These valves relieve high pressure in pipe lines. This valve protects pipe from sudden increase in pressure. It is a device attached with a boiler or other vessel for relieving the pressure of steam automatically before it becomes enough to cause burst**.**



3. **Check valves:**
   These are also called reflux valves or non return valves and are automatic devices which allow water to flow only in one direction and prevent it from flowing it in reverse direction.



4. **Air relief valves:**
When water enters in pipe lines it also carries some air with it which tends to accumulate at high points of the pipe. When the quantity of air increases it cause the serious blockage of water. Therefore it is most essential to remove the accumulated air from the pipe line. Air relief valves are used for this purpose.



5. **Drain valves:**
In the summits of mains it is possible that some suspended impurities may settle down and cause obstruction to the flow of water. In the distribution system at dead ends if water is not taken out it will stagnate and bacteria will grow in it. To avoid the above difficulties, drain valves are provided at such places. These are also called scour valves or blow off valves. At the summit of main pipe a branch is taken off from the lowest point in which drain valve is fixed. When drain valve is opened the water rushes out thus removing all the silt, clay etc. from the main line.

6. **Hydrants:**
These devises are used for taping water from mains for fire extinguishing, street, washing, watering gardens, flushing sewer lines and for so many other purposes. These are generally provided at all junctions of roads and at 100 -130 m apart along the roads.
Hydrants are of two types
1. Flush hydrant
2. Post hydrant
1. Flush hydrant:
It is installed in underground brick chamber flush with the foot path. It is covered by a cast iron cover to locate the position of this hydrant even in darkness. Some distinct sign is provided near it at the side of the road.
2. Post hydrant: The barrel of the hydrant remains projected about 60-90 cm

above the ground surface. These hydrants have a long stem with screw and nut at the top to regulate the flow of water. The post hydrant is connected to the pipe and it can be operated by means of a gate valve.

Meters:

To determine the quantity of water flowing through water pipes some devices are required which are called meters. Meters can be classified as follows

1. The positive displacement type
2. The velocity inferential type

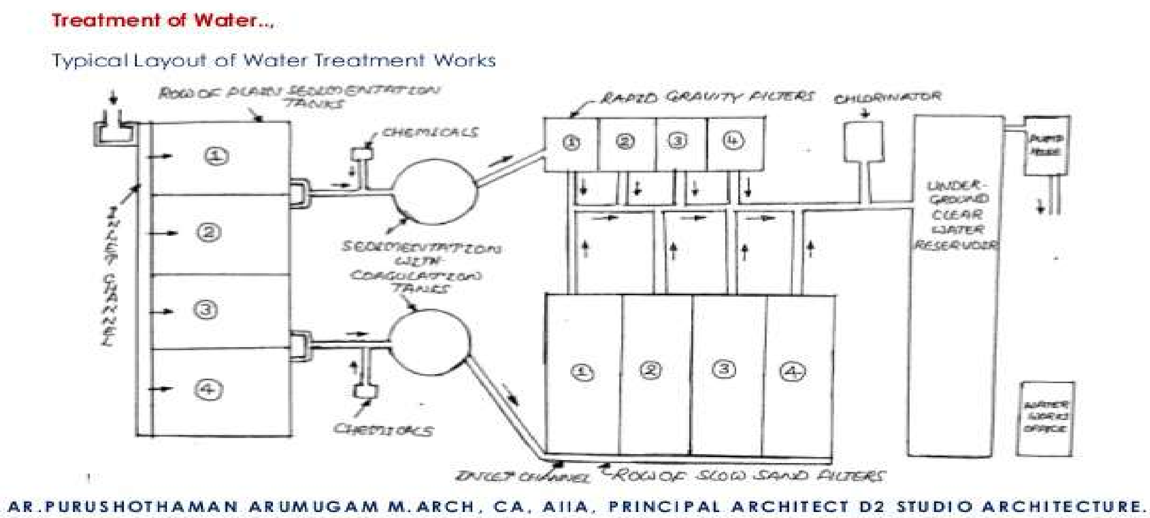
1. **The positive displacement type**: These are used for measuring small flows of water. These are designed on displacement principle and record the number of times a vessel of known volume is filled and emptied. From this the rate of flow is calculated automatically. These types of meters include rotary, reciprocating, oscillating and nutating disc meters.
2. **The velocity inferential type**: These are generally venturi or turbine type. They consist of a device which a vane or propeller turns in direct ratio to the rate of flow of water around the propeller. The venturimeter consist of two cast iron conical pipes, one long and other short, joined together at their small ends. Two vertical piezometer tubes are provided one at the big end of short reducer and second at the junction of small end. The piezometer tubes are connected to an apparatus which measure the difference of water level between them. By means of an automatic device a graph is recorded of the discharge through the venturi tube.

Layout of treatment plant:

One complete water treatment plant requires the following process starting from the source of water up to the distribution zone in order of sequence.

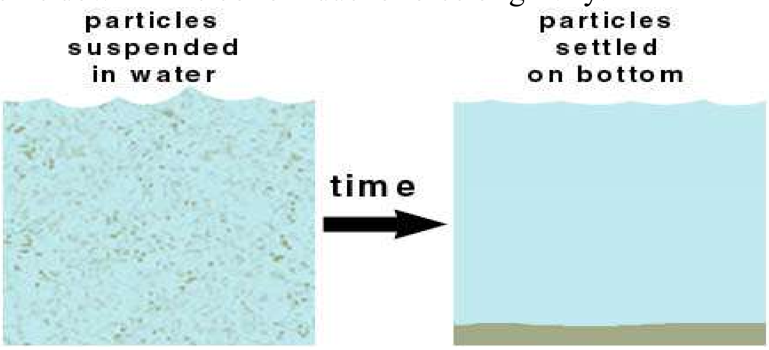
1. Intake work including pumping plant
2. Plain sedimentation
3. Sedimentation with coagulation
4. Filtration
5. Water softening point
6. Miscellaneous treatment plants
7. Disinfection
8. Clear water reservoir
9. Pumps for pumping the water in service reservoir

(10) Elevated or underground service reservoir



Sedimentation:

If the water contains suspended impurities of large size, it is very economical to remove them by preliminary sedimentation. The suspended impurities make the water turbid, therefore, when they will be removed, more uniform water will be available for further treatment. Plain sedimentation is the process of removing suspended matter from the water by keeping in quiescent conditions in the tanks, so that suspended matter may settle down in the bottom due to force of gravity.



Classification of sedimentation tanks:

On the basis of their purpose and design, the sedimentation tanks can be classified as follows:

1. Grit chambers for removal of sand and silt.
2. Plain sedimentation tanks for removal of nearly settleable solids.
3. Chemical precipitation tanks for removal of very fine suspended matter, by adding coagulants.
4. Septic tanks for doing sedimentation and sludge digestion in the same compartment.
5. Imhoff tanks also known as two storey tanks, in which sedimentation and sludge digestions are done in different compartments.
6. Secondary settling tanks – in these tanks effluent from activated sludge process or tricking filters is allowed to settle.

Depending upon the direction of flow of sewage.

1. Horizontal flow settling tanks
2. Vertical or upward flow settling tanks
3. Radial flow settling tanks

Principle of sedimentation:

Sedimentation is done to remove the impurities which have specific gravity more than that of water and are settleable. When water is moving these impurities remain in suspension due to the turbulence and as the velocity is reduced they settle down. It is not necessary to stop the motion of water completely as it will require more volume of the sedimentation tanks. As per the theory of sedimentation the settlement of a particle depend upon the velocity of flow, the viscosity of water, the size shape and specific gravity of particle. The settling velocity of a spherical particle is expressed by Stoke's law which gives the final equation as follows,

$$V_s = g/18\ (S_s-1)\ d^2/\mu$$

V_s = Velocity of settlement of particle in m/sec
d = diameter of the particle in cm
S_s = specific gravity of the particle
μ = kinematic viscosity of water in m^2/sec

Knowing the settling velocity of particle, that is intended to be settled, the design of the settling tank is done.

Design factors of sedimentation:

The continuous flow type of sedimentation tanks are widely adopted at present and hence, it becomes essential to study in detail some of the design factors of these tanks.

1. **Velocity of flow**: The velocity of water in sedimentation tanks should be sufficient enough to cause hydraulic subsidence of suspended impurities. It should remain uniform throughout the tank and it is generally not allowed to exceed 15 cm to 30 cm/min.

2. Capacity of tank: Following are the two methods by which capacity of sedimentation tank is determined:

1. **Detention period**: The theoretical time taken by a settling tank is known as detention period, the relation between capacity and detention period is

$T = C/Q$ = capacity of tank / rate of flow per meter

For plain sedimentation T varies from 4 to 8 hours when coagulants are used, it may vary from 3 to 4 hours.

In this method the depth of the tank provided for settling tank vary from 3 to 6 m

(ii) **Over flow r**ate: In this method it is assumed that the settlement of a particle at the bottom of the tank does not depend on the depth of the tank. But it depends on the surface area of the tank.

$$T = C/Q = L*B*D/Q$$

And also $T = D/V$ = distance of descend/velocity of descend

Now equating above two equations

$$L*B*D/Q = D/V$$

Or $V = Q/L*B$

V = surface over flow rate

From the above equation it can be stated that the quantity of water passing per hour per unit area of settling tank is known as surface over flow rate. For plain rectangular sedimentation tans, it is about 500-750 lit/hr/m^2 and when coagulants used, it is about 1000-1250 lits/hr/m^2 of plan area.

3. **Inlet and outlet arrangement**
4. **Shapes of tank**
5. **Miscellaneous considerations**

1. Construction of tanks **(iii)** Free board

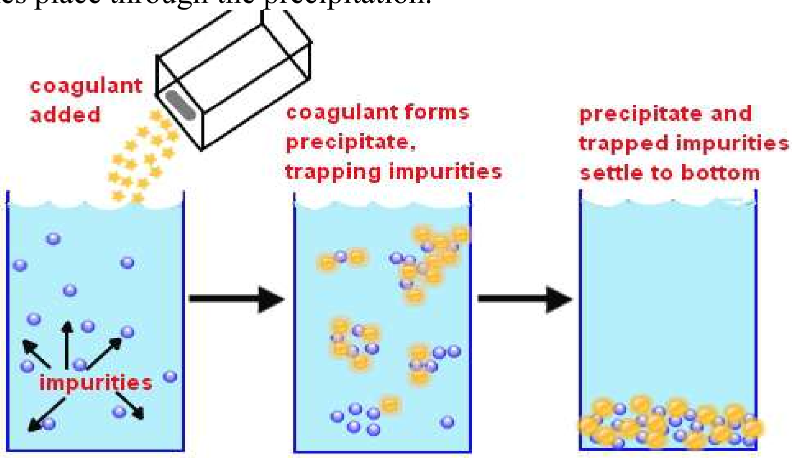
(ii) Sludge capacity **(iv)** Sludge removal

Coagulation: Solids are removed by sedimentation (settling) followed by filtration. Small particles are not removed efficiently by sedimentation because they settle too slowly; they may also pass through filters. They would be easier to remove if they clumped together (coagulated) to form larger particles, but they don't because they have a negative charge and repel each other**.** In coagulation, we add a chemical such as alum which produces positive charges to neutralize the negative charges on the particles. Then the particles can stick together, forming larger particles which are more easily removed.

Sedimentation with coagulation:

Very fine suspended particles are not removed by plain sedimentation. When particles contain such fine clay particles and colloidal impurities, it becomes necessary to apply such process which can easily remove them from the water. After long time it has been found that such impurities can be removed by sedimentation with coagulation.

First the coagulants are mixed in water to produce the required precipitate, then the water is sent to sedimentation basins where sedimentation of fine and colloidal particles takes place through the precipitation.



Following six are the usual coagulants which are adopted for coagulation

1. Aluminium sulphate
2. Chlorinated copperas
3. Ferrous sulphate and lime
4. Magnesium carbonate
5. Polyelectrolytes
6. Sodium aluminate

The dosage of coagulants which should be added in the water, depends on the following factors

1. Kind of coagulant
2. Turbidity of water
3. Colour of water
4. pH value of water
5. temperature of water
6. mixing and flocculation time

Flocculation:

The floc produced by the action of coagulants with water is heavy and hence, it starts to settle down at the bottom of tank. As it descends, it absorbs and catches more and more suspended impurities present in water. It thus slowly goes on increasing in size. During this process, some amount of bacterial removal also takes place. The surface of floc is sufficiently wide to arrest colloidal and organic matter present in water. The term flocculation is used to denote the process of floc formation and thus flocculation follows the addition of coagulant.
Its efficiency depends on the following factors

1. Dosage of coagulant

The dosage or quantity of coagulant should be carefully determined so as to cause visible floc. The quantity of coagulants should be such that turbidity of water is brought down to the limit of 10 to 25 p.p.m.

2. **Feeding**

The feeding of coagulants may be in powder form or in solution form, the latter being more popular

3. **Mixing**

The coagulants should be properly mixed with water so as to cause a uniform mass. In the beginning, the mixing may be quick for a period of about 30 to 60 seconds or so.

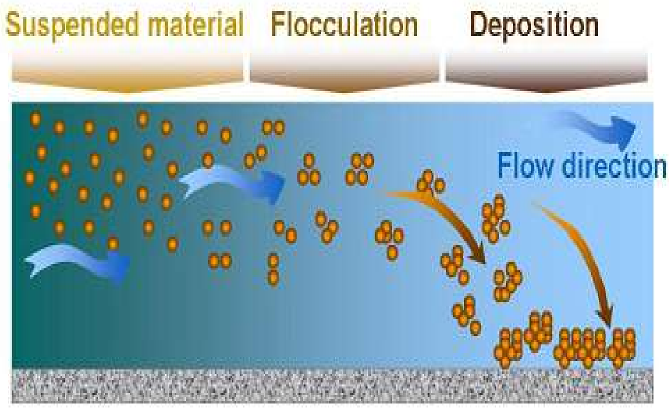
4. **pH value**

Depending upon the quality of water and coagulant adopted, suitable pH value should be determined. The pH value should be actually tested in the laboratory at regular intervals. To remove acidity, lime is added to water and to remove alkalinity, sulphuric acid is added to water.

5. **Velocity**

The floc should be allowed to move gently after initial quick mixing, The gentle movement of floc results in collision of particles and ultimately, the floc grows in size. The detention period of coagulated sedimentation tanks is about 3 to 4 hours.

The processes of coagulation and flocculation are greatly influenced by the physical characteristics of water, its dissolved constituents and the temperature. The failures in coagulation plant are due to incorrect does of the coagulant, inadequate mixing arrangements, improper tank design, etc. Hence, the characteristics of water to be submitted to the coagulation plant should be properly studied before deciding the details of the plant.



UNIT – 3

WATERSUPPLY

WATER DISTRIBUTION SYSTEM:

The purpose of distribution system is to deliver water to consumer with appropriate quality, quantity & pressure.

Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage.

REQUIREMENT OF GOOD DISTRIBUTION SYSTEM:

- Water quality should not get deteriorated in the distribution pipes.
- It should be capable of supplying water at all the intended places with sufficient pressure.
- It should be capable of supplying the requisite amount of water during fire fighting.
- The layout should be such that no consumer would be without water supply, during the repair of any section of the system.
- All the distribution pipes should be preferably laid one meter away or above the sever line.
- It should be fairly water tight as to keep losses due to leakage to the minimum.

LAYOUTS DISTRIBUTION NETWORK:

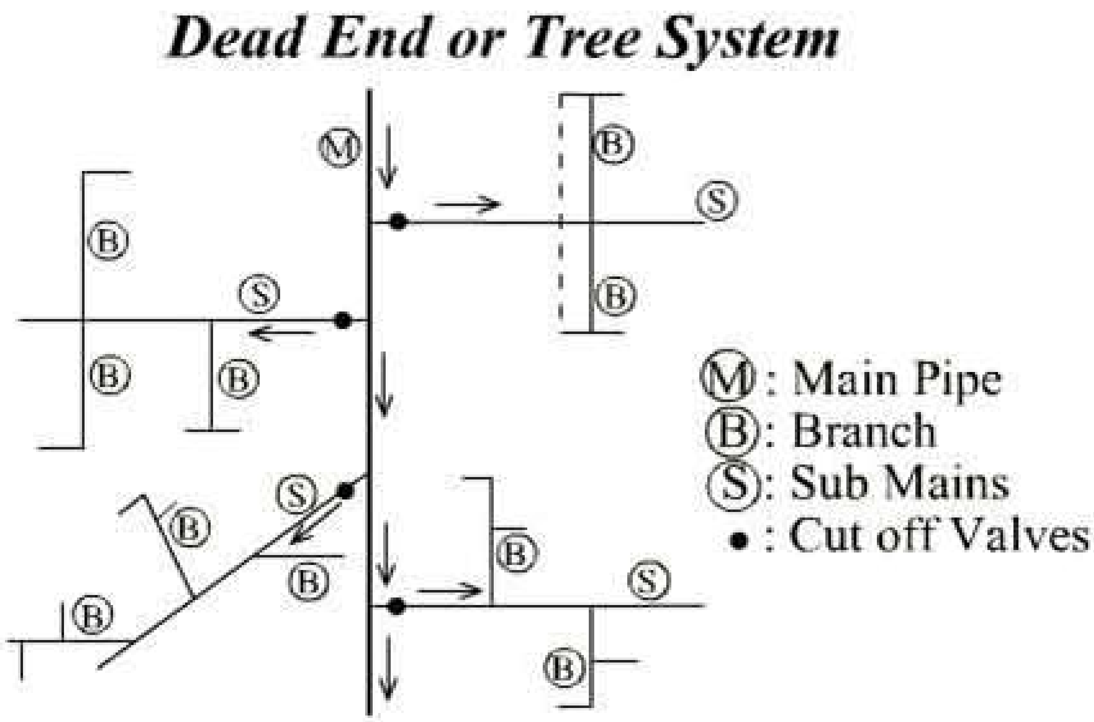
- The distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads.
- There are general, four different types of pipe networks; any one of which either single or in combinations, can be used for a particular place.

CLASSIFICATION OF NETWORKS:

- **Dead End System**
- **Radial System**
- **Grid Iron System**
- **Ring System**

DEAD END SYSTEM:

It is suitable for old towns and cities having no different pattern of roads.



Advantage:-

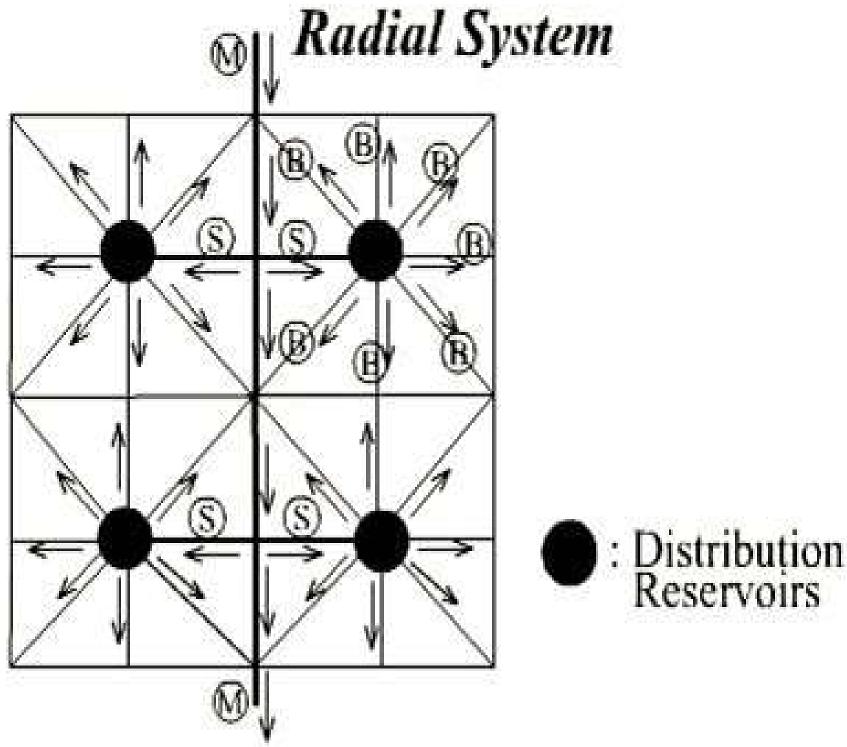
- Relatively cheap
- Determination of discharge and pressure easier due to less number of valves.

Disadvantage:-

- Due to many dead ends, stagnation of water occurs in pipes.

RADIAL SYSTEM:

- The area is divided into different zones.
- The water is pumped into the distribution reservoir kept in the middle of each zone.
- The supply pipes are laid rapidly ending towards the periphery.

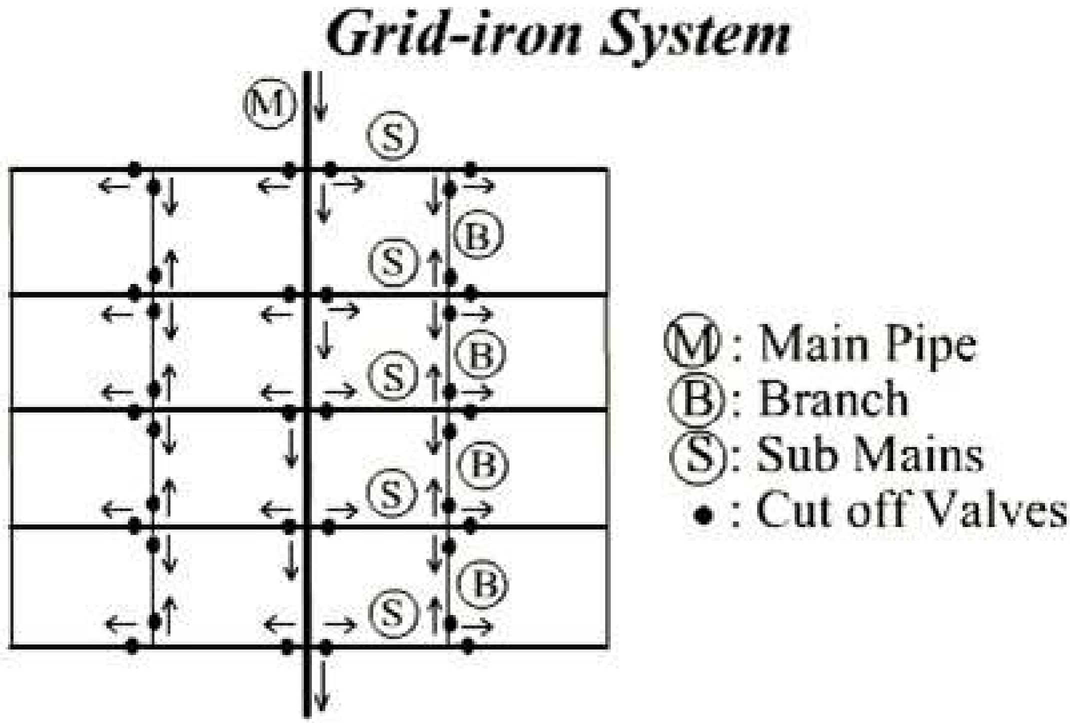


Advantages:-

- It gives quick service
- Calculation of pipe size is easy

GRID IRON SYSTEM:

It is suitable for cities with rectangular layouts, where the water mains and branches are laid in rectangles.



Advantage:-

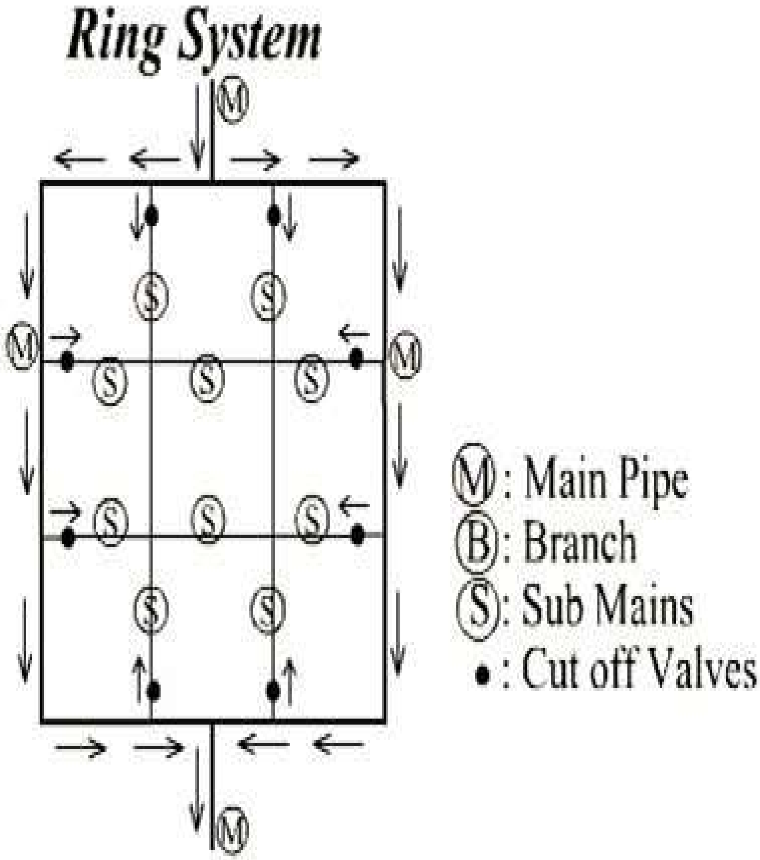
- Water is kept in good circulation due to absence of dead ends
- In the case of break down in some section, water is available from some other direction.

Disadvantage:-

- Exact calculation of sizes of pipes is not possible due to provisions of valves on all branches.

RING SYSTEM:

- The supply main is laid all along the peripheral roads and sub mains branch out from the mains.
- This system also follows the grid iron system with the flow pattern similar in character to that of dead end system.
- So determination of the size of pipes is easy.



Advantages:-

- Water can be supplied to any point from at least two directions.

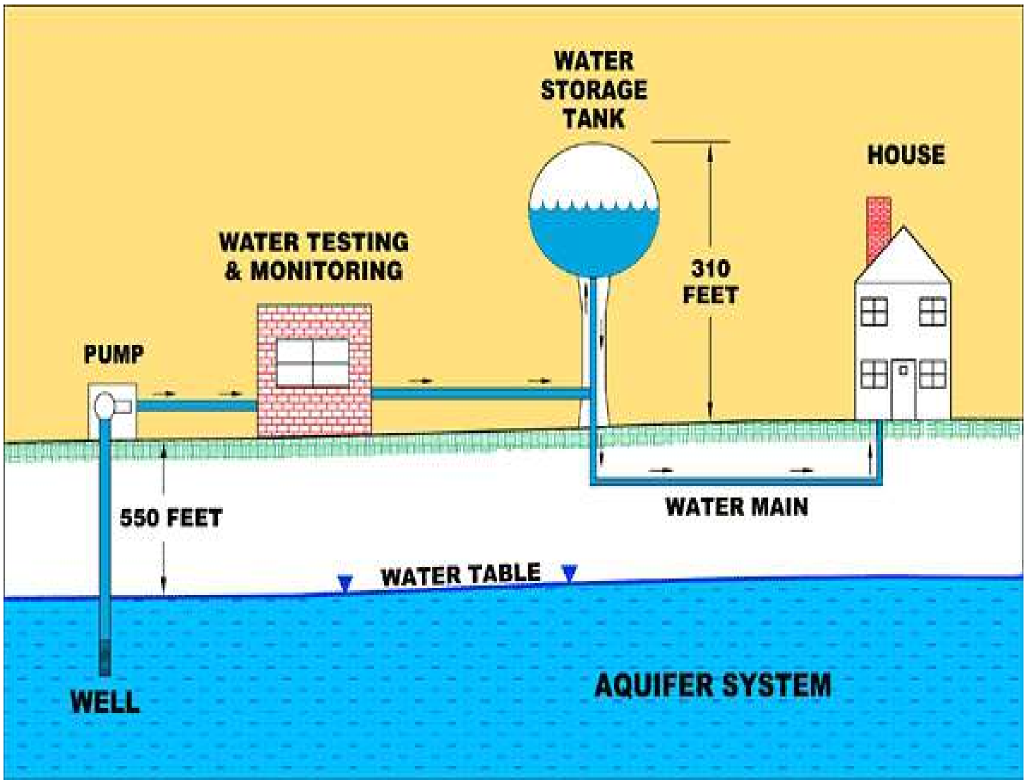
METHODS OF WATER DISTRIBUTION:

For efficient distribution system adequate water pressure required at various points. Depending upon the level of source, topography of the area and other local conditions, the water may be forced into distribution system by following ways

- **Gravity System**
- **Pumping System**
- **Combined gravity and pumping system**

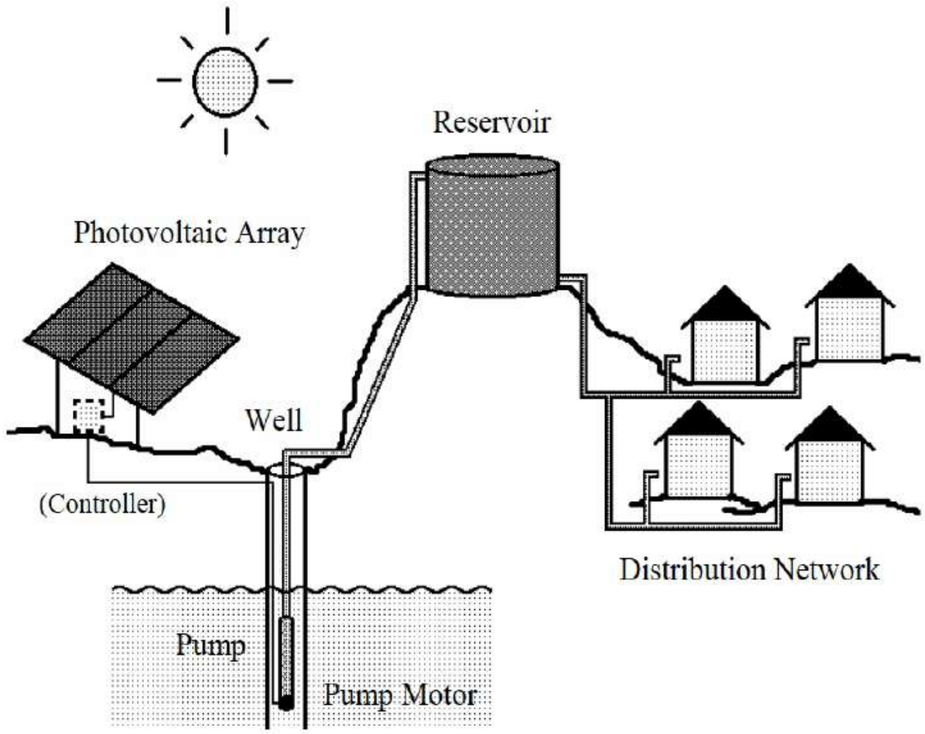
GRAVITY SYSTEM:

- Suitable when source of supply is at sufficient height.
- Most reliable and economical distribution system.
- The water head available at the consumer is just minimum required.
- The remaining head is consumed in the frictional and other losses.



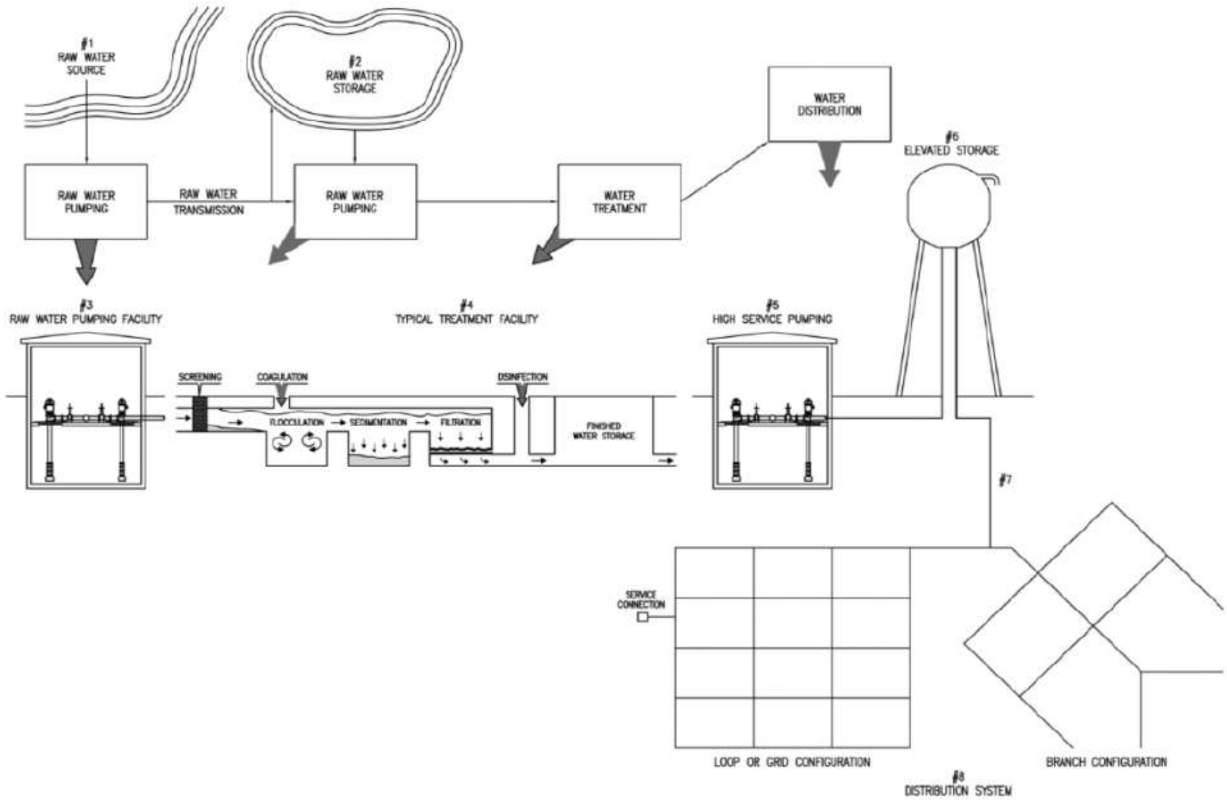
PUMPING SYSTEM:

- Treated water is directly into the distribution main out storing.
- Also called pumping without storage system.
- High lifts pumps are required.
- If power supply fails, complete stoppage of water supply.
- The method is not general used.



COMBINED GRAVITY and PUMPING SYSTEM:

- Most common system
- Treated water is pumped and stored in an elevated distribution reservoir.
- Then supplies to consumer by action of gravity.
- The excess water during low demand periods get stored in reservoir and get supplied during high demand period.
- Economical, efficient and reliable system.



Pipes which are commonly used in water supply system are given below:

- Cast Iron (CI) Pipes.
- Steel Pipes.
- Galvanized Iron (GI) Pipes.
- Copper Pipes.
- Plastic or Polythene or PVC pipes.
- Asbestos Cement (AC) Pipes.
- Concrete Pipes.

Piping Network:

Analysis of water distribution system includes determining quantities of flow and head losses in the various pipe lines, and resulting residual pressures. In any pipe network, the following two conditions must be satisfied:

1. The algebraic sum of pressure drops around a closed loop must be zero, i.e. there can be no discontinuity in pressure.
2. The flow entering a junction must be equal to the flow leaving that junction; i.e. the law of continuity must be satisfied.

Based on these two basic principles, the pipe networks are generally solved by the methods of successive approximation. The widely used method of pipe network analysis is the Hardy-Cross method.

Installation of Pipe Network:

Installation of steel piping was slow and tedious, because lengths between fittings had to be cut exact, and then fastened together with threaded joints, one following another in progression.

Copper pipe was developed, along with a new type of fitting to connect joints. Pipe and joints no longer needed to be threaded. Copper piping is joined together with brass fittings, in a connection called a "sweated Joint." A brass fitting is heated with a gas torch so the material expands. While it is still hot, the fitting easily slides over the outside of the end of the pipe, and when it cools, the fitting contracts against the pipe to make a tight fit. The connection is then soldered.

Plastic piping, such as polyvinylchloride (PVC) was developed into an economical and efficient system, but is not suitable for water piping under pressure inside buildings. The fittings and methods of joining are not dependable enough to trust against a leak that might occur inside a wall or an attic. But PVC piping is used extensively where piping is installed outside of habitable buildings.

Within the past several years a high strength plastic pipe has been developed that is suitable for high pressure water systems, and is approved by most building codes. The fittings are made of brass and the connections by steel crimps. The major advantage of the material is that it is manufactured in long rolls, making installation easier because it eliminates many joints in a system.

Another advantage is that the material for cold water use is translucent white, and the material for hot water use is translucent red. The pipe also comes in blue. Material is manufactured under the name “Wirsbo-pex.” Wirsbo is a manufacturer’s name, and “pex” is a chemical acronym for “polyethylene cross-linked,” hence the X.

Plumbing fixtures; sinks, lavatories, closets, faucets, etc., are rated by water use in terms of FIXTURE UNITS. A fixture unit once was defined as one cubic foot of water, but that definition has no specific meaning in sizing piping. Fixtures defined by fixture units is a comparison of the amount of water used – and these comparisons have led to the development of a chart defining gallons per minute demand, based on quantities of fixtures, and a reasonable assumption of frequency of simultaneous use of fixtures.

In other words, the more fixtures that are installed within a system, the less likely that all fixtures are used at the same time. So demand in gpm is less per fixture unit as the number of fixture units increase.

TYPES OF JOINTS:

- **End Cap Joint-** comprises a cylindrical gasket-type fitting formed of soft, malleable material. The end cap is connected to the end of an air filter with an adhesive. The end cap has a general “U” shaped end portion that encases one end of the air filter and includes a locking tab. The locking tab is formed on the end cap's interior lip to assist in holding the end cap in place. Pre-moulded air filter end caps are primarily designed for use in safety air filters for heavy motor vehicle applications, specifically, off road vehicles such as bulldozers, bob cats & transfer trucks.

- **Tee Joint-**

Which have long functional life and exhibit efficient performance. Our products are useful to connect pipes of diverse diameters. These easy operational joints are used in different industrial applications for changing the pipe run direction. The precisely engineered **Tee pipe join** are known for their durability and sturdy construction.

➢ **Strainer Joints –**

These are specially designed for piping system. There are different types of strainer joints, which have different designs and sizes. The chief material used for manufacturing these joints are carbon & stainless steel, which give them longer life and high performance. These materials are in accordance to international quality standards.

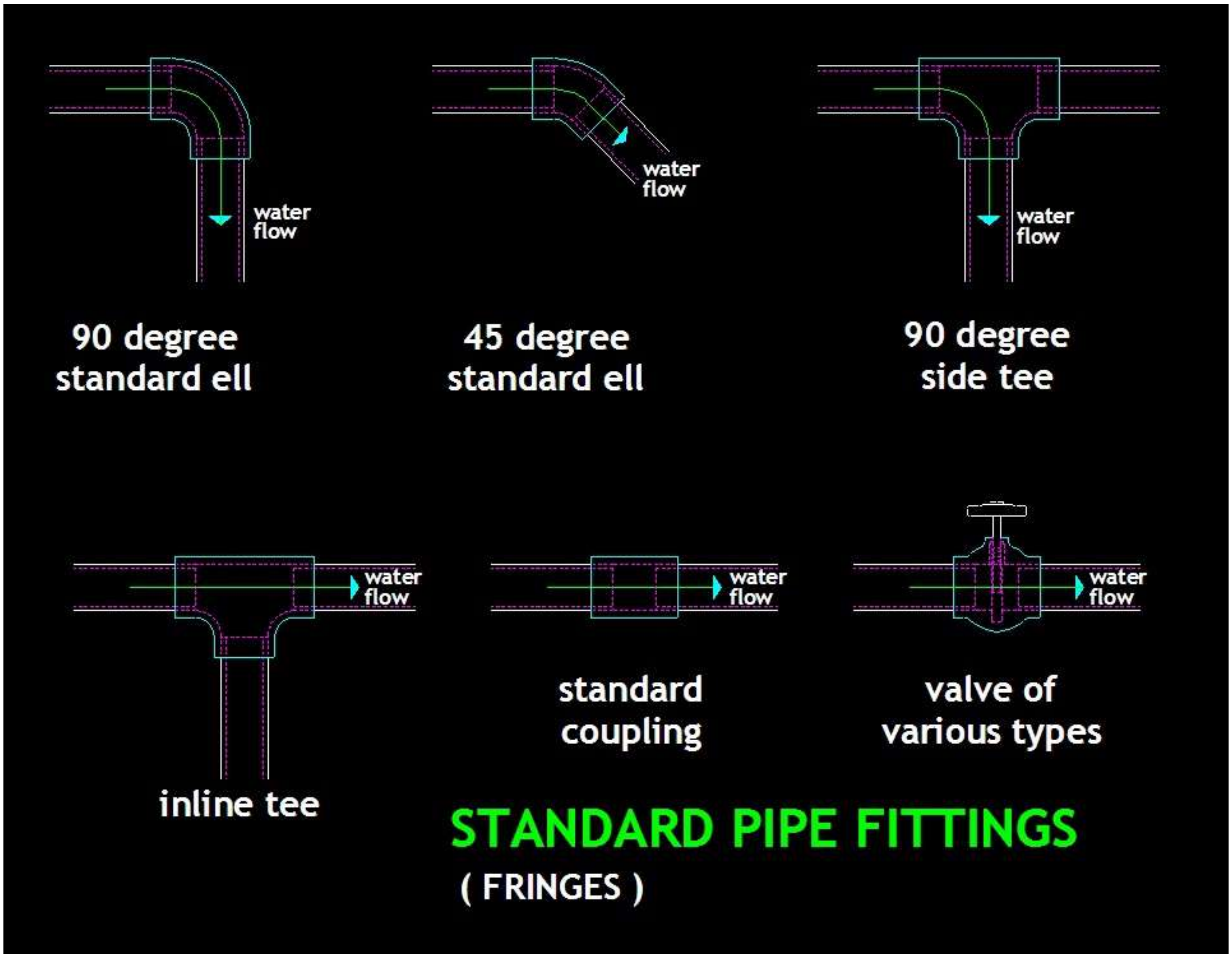
➢ **Reducer Joint –**

These are catering the needs of different industries across the domestic market. These joints are popular for their non-abrasive nature, anti corrosive property and high durability. These products are easy to install and are made from high quality alloy steel, carbon steel, stainless steel and nickel alloys. These reducer joints are used to prevent fluid leakage and enhance the functionality in an effective manner.

- **Cast Iron Bent Joint –**

  These are available in various designs and sizes that is used for joining pipes. Another important feature of these joints is that they provide easy passage to tools and shafts for effectual cleaning. Our products are available at reasonable rates according to the industry related prices. These are beneficial in meeting the exact application demand by installation at different angles.

STANDARD PIPE FITTINGS:



Valves:

The most common use for valves in a distribution system is to isolate sections of pipe so that repairs can be made. Valves used for this purpose are often called 'isolation valves'. As well as allowing repairs to be made, isolation valves also allow flushing to be carried out effectively and-fire fighting water to be accessed.

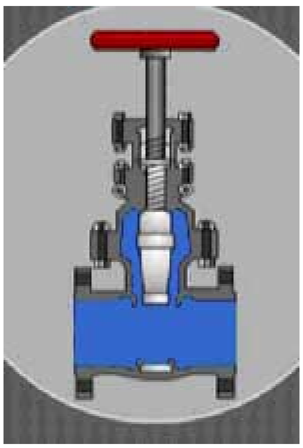
Other important valves include fire hydrants, pressure-reducing valves and air valves.

9.1 Common isolation valves:S

9.1.1 Gate valves and sluice valves

Gate valves are the most common valves in distribution systems operated by local authorities. Gate valves have a solid plate that slides down to block the flow of water. When the valve is opened (by raising the plate), there is no obstruction to the flow of water through the valve.

Figure 13: A gate valve



Resilient-seated gate valves have a rubber coating on the gate or the wall the gate touches when it is closed. The rubber coating improves the seal and prevents damage to the valve when there is debris in the pipe.

Knife-gate valves have a narrow gate, which makes the valves smaller and easier to fit into tight spaces. They are generally not suitable for burying in the ground, which makes them less useful for water distribution systems.

Gate valves are often called 'sluice valves' when they are resilient seated and the valve is 100 mm diameter or larger.

9.1.2 Globe valves

Globe valves work by pushing a hemispherical globe or circular plate against a hole. The edge of the hole where the globe contacts when closed is called the valve seat. Most household taps and stop cocks are globe valves.

Figure 14: A globe valve

9.1.3 Butterfly valves

A butterfly valve has a round, flat plate that is mounted on a shaft that passes directly through the middle of the valve body. By turning the shaft through 90º the plate is rotated to seal off the flow.

Figure 15: A butterfly valve

Butterfly valves are cheaper than gate valves. They are not commonly used in local authority water distribution systems but they are common around water treatment plants. Pipelines with butterfly valves in them cannot be swabbed, and serious water hammer can occur if a butterfly valve is opened or closed too quickly.

9.2 Fire hydrants

Fire hydrants are typically a globe valve in an epoxy-coated cast-iron body. A fire hydrant is designed to shut off completely for long periods of time, but when required they must reliably open and provide a high flow at a low pressure drop. Due to the flows and pressures required, fire hydrants are seldom installed on pipes of less than 100 mm nominal bore.

9.3 Pressure-reducing valves

Pressure-reducing valves are normally used when the distribution system is in a hilly area and the effect of gravity means that pressures are too high for customers living at low elevations. Pressure-reducing valves allow different pressure zones to be created for each elevation.

Figure 16: A pressure-reducing valve

Because leakage rates increase with pressure, reducing the system pressure in this way can also save water.

9.4 Air relief valves

Air relief valves are installed at high points of long water pipes to release the air that gathers in these places. Allowing air to collect can significantly reduce the flow capacity of the pipeline. Fire hydrants or small gate valves can also be used to manually remove this air.

Low-pressure pipelines, such as some trunk mains, may need vacuum relief valves. These valves let air into the pipeline to protect the pipeline from negative pressures that would otherwise collapse the pipe when it empties.

UNIT –IV

Objective: i) The main objective is to understand the sewerage system and its components

ii) To understand the sludge digestion process and techniques

Syllabus: characteristics of sewage-examination of sewage- C.O.D, B.O.D equations- ultimate disposal of sewage- one pipe and two pipe systems of plumbing- house drainage-components-requirement sanitary fittings- traps- sewer appurtenances- oxygen sag curve-introduction to aerobic and anaerobic ponds- oxidation ponds.- sludge digestion tanks and soak pits- working principles ad design of septic tank.

Learning Outcomes: After learning this unit the student will able to

i) To estimate the oxygen demand for the polluted water

ii) To apply knowledge in the design of septic tanks ,oxidation ponds and soak pits.

SEWAGE HANDLING AND TREATMENT OF SEWAGE AND SLUDGE

Sewage is a water-carried waste, in solution or suspension that is intended to be removed from a community. Also known as domestic or municipal wastewater, it is characterized by volume or rate of flow, physical condition, chemical and toxic constituents, and its bacteriologic status (which organisms it contains and in what quantities). It consists mostly of grey water (from sinks, tubs, showers, dishwashers, and clothes washers), black water (the water used to flush toilets, combined with the human waste that it flushes away); soaps and detergents; and toilet paper (less so in regions where bidets are widely used instead of paper). Whether it also contains surface runoff depends on the design of sewer system.

All sewage ends up back in the environment (from which its constituents came), by any of several routes. A basic distinction in its route is whether it undergoes sewage treatment to mitigate its effect on the environment before arriving there. Sewage usually travels from a building's plumbing either into a sewer, which will carry it elsewhere, or into an onsite sewage facility (of which there are many kinds). Whether it is combined with surface runoff in the sewer depends on the sewer design (sanitary sewer or combined sewer).

Sewage Characteristics

Characterization of wastes is essential for an effective and economical waste management programme. It helps in the choice of treatment methods deciding the extent of treatment, assessing the beneficial uses of wastes and utilizing the waste purification capacity of natural bodies of water in a planned and controlled manner. While analysis of wastewater in each particular case is advisable, data from the other cities may be utilized during initial stage of planning. Domestic sewage comprises spent water from kitchen, bathroom, lavatory, etc. The factors which contribute to variations in characteristics of the domestic sewage are daily per capita use of water, quality of water supply and the type, condition and extent of sewerage system, and habits of the people. Municipal sewage, which contains both domestic and industrial wastewater, may differ from place to place depending upon the type of industries and industrial establishment.

Characteristics of waste water classified into 3 heads

a) physical characteristics
b) chemical characteristics
c) biological characteristics

Physical characteristics

i) Colour
Fresh domestic sewage will be in grey colour as time passes it gets dark or black in colour and the industrial sewage colour depends on the process
ii) Odour
Fresh sewage has a musty odour within 3 to 4 hrs. It gets stale. Odour evolves due to emitting of methane gas.
iii) Temperature
Temperature of waste water slightly higher than water supply. Ideal temp. for biological activity in water 20 degrees Centigrade. and rises up to 60. Increase in temp. of waste water, when discharging into water bodies affects the aquatic life.
iv) Turbidity
It depends on the quantity of solid matter present in the suspension state. Turbidity test is used to indicate the quality of waste discharges with respect to colloidal matter.
v) Total solids
The suspended solids, colloidal solids and dissolved solids together called as total solids

Chemical characteristics

i) PH value
Fresh water should contain 7.3-7.5
ii) Chloride content
They can be found in domestic sewage. Using silver nitrate solution and potassium dichromate as indicator we can determine.
iii) Nitrogen content
It indicates all the organic matter presented in the waste water

Oxygen demand

O_2 demanded for the bacterial growth to decompose organic and inorganic matter
It is classified into 4 types
i) biochemical oxygen demand (B.O.D)
ii) Chemical oxygen demand (C.O.D.)
iii) total oxygen demand (T.O.D)
iv) theoretical oxygen demand (Th.O.D)

I) B.O.D

Oxygen required to oxidize the organic matter. It is defined as the oxygen required for the micro-organisms to carry out biological decomposition of dissolved solids or organic matter in the water under aerobic conditions at standard temp.

Requirement of B.O.D. determination

*determination of approx. oxygen required for stabilization of organic matter

*determination of size and efficiency of treatment plant, strength of sewage

*dilution ratio

Here first stage of o_2 demand is known as carbonaceous demand and 2nd stage of demand is known as nitrogenous demand.

B.O.D. equation

BOD Model It is generally assumed that the rate at which the oxygen is consumed is directly proportional to the concentration of degradable organic matter remaining at any time. The kinetics of BOD reaction can be formulated in accordance with first order reaction kinetics as:

$d\,Lt / d\,t = -K\,Lt$

Where,

Lt = amount of first order BOD remaining in wastewater at time t

K = BOD reaction rate constant, $time^{-1}$

Integrating $\int d\,Lt / d\,t = -KL\,dL_0$ i.e., time t = 0,

i.e., ultimate first stage BOD initially present in the sample.

The relation between K (base e) and K (base 10) is K(base 10) = K(base e) / 2.303 The amount of BOD remaining at time 't' equals

$Lt = Lo\,(e^{-k.t})$

The amount of BOD that has been exerted (amount of oxygen consumed) at any time t is given by $BOD_t = Lo - Lt = Lo\,(1 - e^{-k.t})$ and the five day BOD is equal to

$$BOD_5 = Lo - L_5 = Lo\,(1 - e^{-5k})$$

For polluted water and wastewater, a typical value of K (base e, 20°C) is 0.23 per day and

K (base 10, 20°C) is 0.10 per day.

These values vary widely for the wastewater in the range from 0.05 to 0.3 per day for base 10 and 0.23 to 0.7 for base e.

The ultimate BOD (L_0) is defined as the maximum BOD exerted by the wastewater. It is difficult to assign exact time to achieve ultimate BOD, and theoretically it takes infinite time. From the practical point of view, it can be said that when the BOD curve is approximately horizontal the ultimate BOD has been achieved. The time required to achieve the ultimate BOD depends upon the characteristics of the wastewater, i.e., chemical composition of the organic matter present in the wastewater and its biodegradable properties and temperature of incubation. At higher temperature for same concentration and nature of organic matter ultimate BOD will be achieved in shorter time as compared to lower temperatures, where it will require more time. The ultimate BOD best expresses the concentration of degradable organic matter based on the total oxygen required to oxidize it. However, it does not indicate how rapidly oxygen will be depleted in receiving water. Oxygen depletion is related to both the ultimate BOD and the BOD rate constant (K). The ultimate BOD will increase in direct proportion to the concentration of biodegradable organic matter.

The BOD reaction rate constant is dependent on the following:

1. The nature of the waste

2. The ability of the organisms in the system to utilize the waste

3. The temperature Nature of the waste

Thousands of organic matter exists with different chemical composition in nature. All organic matter will not have same degradation rate. Simple sugar and starches are rapidly degraded and will therefore have a very large BOD rate constant. Cellulose degrades much more slowly and hairs are almost undegradable during BOD test or during biological treatment of wastewater. Other compounds are intermediate degradable between these extremes. For complex waste, like sewage, the BOD rate constant depends upon the relative proportions of the various components. The BOD rate constant is high for the raw sewage (K (base e) = 0.35 -0.7 per day) and low for the treated sewage (K (base e) = 0.12 - 0.23 per day), owing to the fact that, during wastewater treatment the easily degradable organic matter will get more completely removed than the less degradable organics. Hence, in the treated wastewater, relative proportion of the less biodegradable organic matter will be higher, giving lower BOD rate constant.

Ability of organisms to utilize waste: Every microorganism is limited in its ability to utilize organic compounds. Many organic matters can only be utilized by particular group of microorganisms. In natural environment, where the water course is receiving particular organic compound, the microorganisms which have capability to degrade that organic matter will grow in predominant. However, the culture used during BOD test may have very small fraction of the organisms which can degrade that particular organic compounds in the waste. As a result the BOD value, for limited incubation duration, and the rate constant would be lower in the laboratory test than in the natural water where the waste is regularly discharged. Therefore, the BOD test should be conducted with organisms which have been acclimated to the waste so that the rate constant determined in the laboratory can be compared to that in the river.

Temperature: The biochemical reactions are temperature dependent and the activity of the microorganism increases with the increase in temperature up to certain value, and drop with decrease in temperature. Since, the oxygen utilization in BOD test is caused by microbial metabolism, the rate of utilization is similarly affected by the temperature. The standard temperature at which BOD is determined is usually 20oC. However, the water temperature may vary from place to place for the same river; hence, the BOD rate constant is adjusted to the temperature of receiving water using following relationship:

$K_T = K_{20}\ \theta\ (T-20)$

Where T = temperature of interest,

K_T = BOD rate constant at the temperature of interest, day^{-1}

K_{20} = BOD rate constant determined at 20oC, day^{-1}

θ = temperature coefficient.

This has a value of 1.056 in general and 1.047 for higher temperature greater than 20^oC. This is because increase in reaction rate is higher when temperature increases from 10 to 20^oC as compared to when temperature is increased from 20 to 30^oC.

Example: The wastewater is being discharged into a river that has a temperature of 15^oC. The BOD rate constant determined in the laboratory for this mixed water is 0.12 per day. What fraction of maximum oxygen consumption will occur in first four days?

$K_{15} = K_{20}\ (1.056)\ (T-20) = 0.12\ (1.056)(15-20) = 0.091$ per day

Using this value of K to find the fraction of maximum oxygen consumption in four days:

$BOD4 = Lo\ (1 – e^{-0.091x4})$

Therefore, BOD_4 / Lo = 0.305

Chemical Oxygen Demand (COD)

• In this test to determine the oxygen requirement of the wastewater, strong oxidizing agent 'potassium dichromate' is used.

• Acidic environment is provided to accelerate the reactions by addition of sulphuric acid.

• The reflux flasks (closed reflux vials), used for the test, are heated to 150oC for two hours with silver sulphate as catalyst. When silver sulphate catalyst is used, the recovery of most organic compounds is greater than 92 percent.

• COD test measures virtually all oxidizable organic compounds whether biodegradable or not, except some aromatic compounds which resists dichromate oxidation.

• The COD is proportional to BOD only for readily assimilable organic matter in dissolved form e.g. sugars.

• No correlation between BOD and COD exists when: o Organic matter is present in suspended form, under such situation filtered samples should be used. o Complex wastewater containing refractory substances.

• For readily biodegradable waste, such as dairy COD = $BOD_u/0.92$

System of Plumbing

• Single stack system

• One pipe system

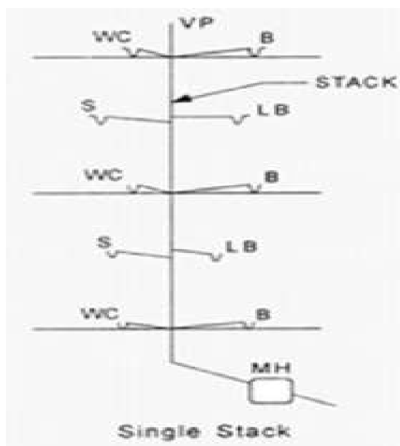
• Partially ventilated single stack system

• Two pipe system.

Single stack system:

• In this system, the waste water from bathroom, kitchen, wash basin, urinals etc and human excreta from water closet is discharged through a single soil pipe and also this pipe acts as ventilating pipe.

• The traps should have water seals at all times at least to a depth of 75mm.



• **Advantages:**

–Simplicity of layout, design and plumbing.

–More economical.

–Improved external appearance because of single pipe.

–Compact plumbing.

• **Disadvantages:**

–Water seals may be evaporated during dry weather.

–Possibility of self or induced syphonage leads sucking of water seals.

–Due to blockage or bad design, the waste water from drainage pipes may be forced up through traps by back pressure.

One Pipe System:

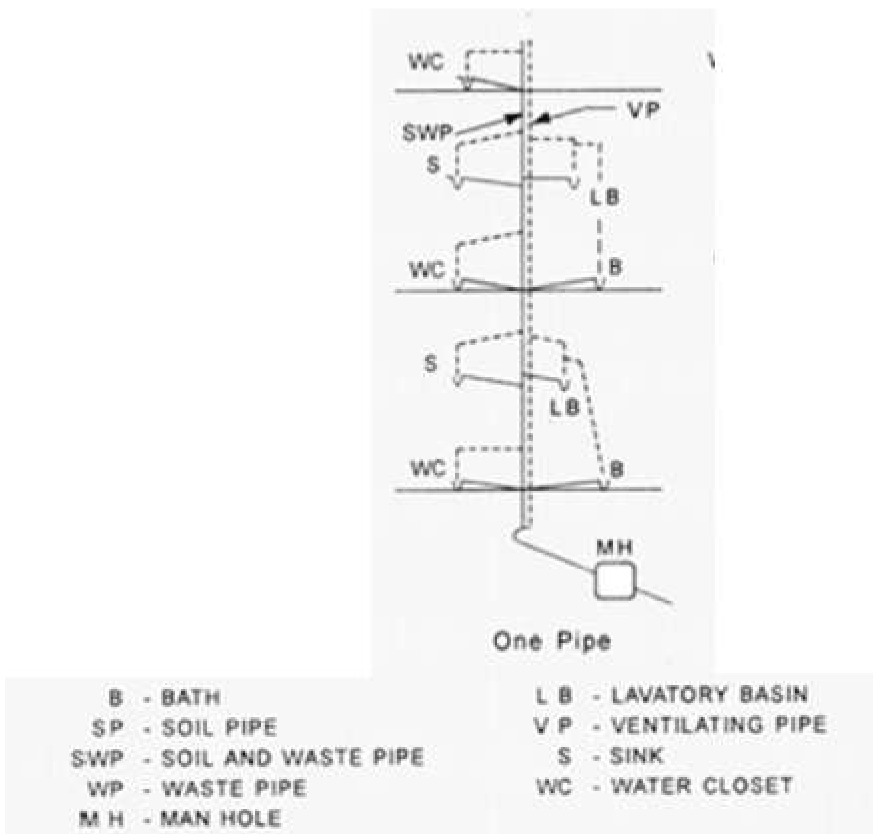
• A separate vent pipe is provided.

• Traps of all water closets, basins etc. are completely ventilated.

• In multistory building to use these system toilet blocks of various floors are placed one over other.

• Waste water discharged from the different units can be carried through short branch drains to common soil and waste pipe (S.W.P.)

• System is bit costlier than single stack system.



Two pipe system:

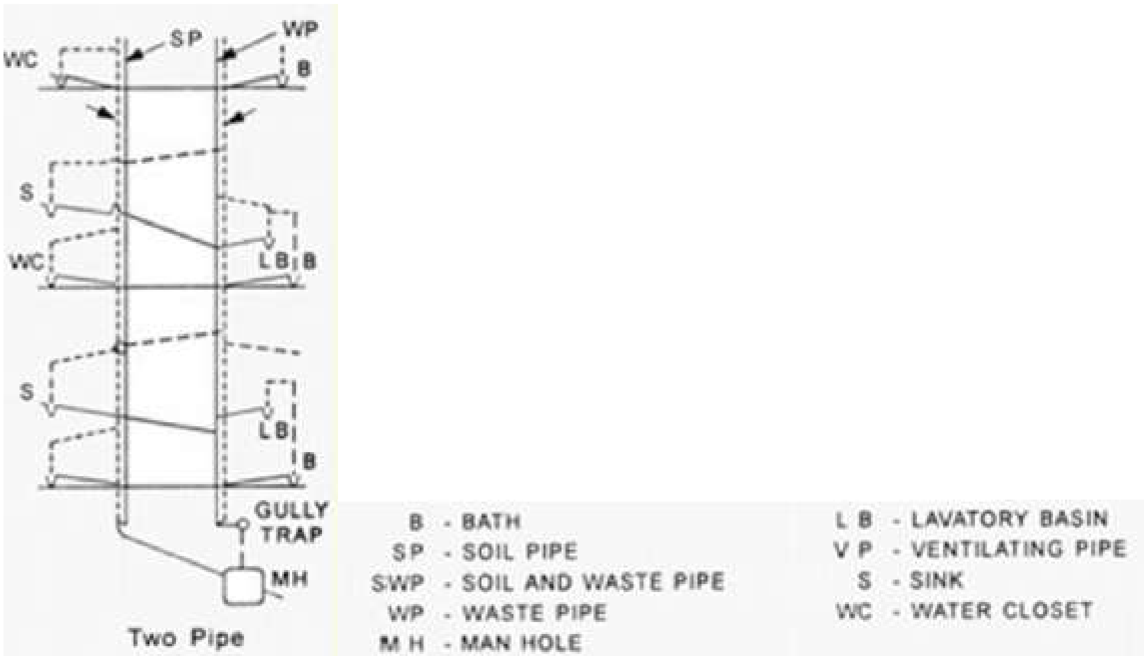
• Separate provision for Soil Pipe and Waste Pipe is provided.

• The discharge from W.C. is connected to the soil pipe.

• While the discharge from baths sinks, lavatory basin etc. is connected to the waste pipe.

• All the traps are completely ventilated by providing separate ventilating pipes. • Thus, four pipes are required.

• The discharge from waste pipe disconnected from the drain by means of a gully trap.



Anti-siphonage pipe

• Pipe installed to preserve the water seal of traps.

• Maintains proper ventilation and does not allow the siphonicaction to take place.

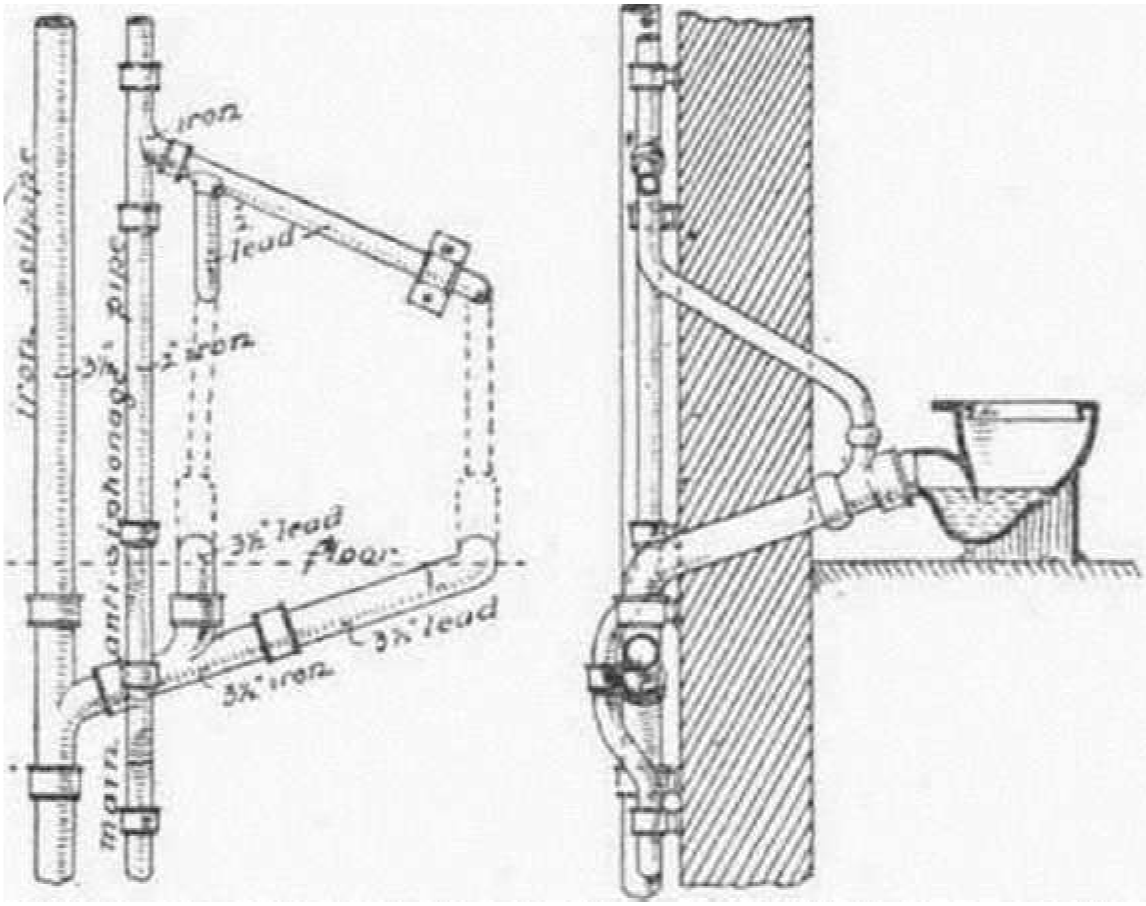
• In case of a multi storied building, the sudden flush of water in the upper story results in the sucking of air from the short branch of the pipe connecting the W.C. to the soil pipe of lower story.

• The sucking of air causes partial vacuum on the downstream side of the water seal of the lower W.C.

• The pressure at the upstream side of the water seal is more which forces the water up the trap and siphons it out in the branch.

• This can be avoided by connecting the crown of the trap to the atmosphere through an antisiphonage pipe

• A ventilating pipe can therefore be used as an antisiphonage pipe.



House Drainage Plan

- Before starting the plumbing work need to prepare drainage plan
- The site plan is drawn to a suitable scale
- Shows position of baths, W.C., urinals, wash basins and other drainage units.
- Shows position of gully traps and floor traps.
- Longitudinal section of the drain is also drawn.
- Sections show distances, invert levels, size and levels of inspection chambers and man holes, gradients of pipes and position and level of public sewer.

Requirement of a good drainage plan

- Quick removal of sewage: – Drains should be laid such that easy and quick removal of sewage is possible.
- Self cleansing: – The slope of the drain should be such that self cleansing velocity is developed in them. – Typical gradients
- 100 mm dia1 in 40 (gradient) • 150mm dia1 in 60 (gradient) • 230mm dia1 in 90

(gradient)

Requirement of a good drainage plan

• Ventilation:

–Entire drainage system should be properly ventilated on the house side

.–The ventilation pipe should be carried sufficiently high above the buildings

–All the inspection chambers should be provided with fresh air inlets.

• Safety: –Drains should be laid in such a way so as to ensure their safety in future.

• Flexibility: –Drains should be laid such that it provides flexibility of expansion, extension, modification and repair.

General rules:

–All soil pipes should be carried directly to the manholes without gully traps.

–Pipes should be laid in straight lines both in horizontal as well as vertical directions.

–Any abrupt change in the direction of flow should be avoided.

–Where pipes intersect or where there is change in the direction of pipe, inspection chamber should be provided.

–All rain water pipes should discharge over gully traps and should be disconnected from the drain.

Partially ventilated single stack system

• Modified form of single stack system and one pipe system.

• Waste from W.C., basins, sinks etc. is discharged into one common soil and waste pipe (S.W.P.).

• However a relief vent pipe is also provides ventilation to the traps of water closets only.

• The traps of basins etc. are not directly connected to the vent pipe.

House drainage

• Drainage system is provided to discharge effectively the sewage of the building into the public sewer. • Domestic sewage or sewage from a building includes human excreta as well as discharge from bathrooms, kitchen, lavatories etc. • Collected by sewers and finally discharge into the public sewer.

Aims of house drainage:

• To maintain healthy and hygienic conditions in the building • Dispose of waste water as early and quickly as possible • Avoid entry of foul gases from the sewer or the septic tank. • Facilitate quick removal of foul matter e.g. human excreta. • Collect and remove waste matter systematically

Principles of house drainage

• Lay sewers by the side of the building rather than below the building. • Drains should be laid straight between inspection chambers, avoiding sharp bends and junctions as far as possible • House drain should be connected to the public sewer only when public sewer is deeper than the house drain in order to avoid reverse flow.

• Lavatory blocks should be located such that the length of the drainage line is minimum. • In case of multistory buildings they should be located one above the other. • At least one wall should be an outside wall, to facilitate the fixing of soil and vent pipes. • Should contain enough traps at suitable points for its efficient functioning.

• Joints of sewer should be water tight and should be properly tested before putting the drainage line to use. • Lateral sewers should be laid at proper gradient so that they can develop self cleansing velocity. • Size of the drain should be sufficient so that they do not over flow at the time of maximum discharge.

• Layout of the house drainage system should permit easy cleaning and removal of obstructions.

• Entire system should be properly ventilated from the starting point to the final point of discharge. House drain should be discontinued to the public sewer by the provision of an intercepting trap. This will avoid the entry of foul gases from entering the house drainage system.

• All the materials and fittings of the drainage system should be hard, strong and resistant to corrosion. They should be non-absorbent type. • The entire system should be so designed that the possibilities of formation of air locks, siphonage, under deposits are minimized. • Rain water pipes should drain water directly into the street gutters from where it is carried to the storm water drain.

Components of Drainage and plumbing system:

- **Pipes**
- **Traps**
- **Sanitary fittings**

PIPES

• In a house drainage system a pipe may have the following designations depending on the function it carries. • Soil pipe: –Pipe carrying sewage from urinals, W.C. etc. • Waste pipe: –Pipe carrying discharges from bath rooms, kitchens, sinks etc. –It does not carry human excreta.

• Vent pipe: –Pipe installed for the purpose of ventilation or to carry foul smell. –Vent pipe is open at top and bottom to facilitate exit of foul gases. –Exit is kept at least 1m above the roof level. • Rain water pipe: –Pipe to carry rain water.

• Anti siphonagepipe: –Pipe installed to prevent the water seal of traps. –Maintains proper ventilation and does not allow the siphonicaction to take place.

• Common sizes of pipes for different functions: Pipe Diameter in 'mm' Soil pipe 100 ,Waste pipe horizontal 30 –50 ,Waste pipe vertical 75, Rain water pipe 75, Vent pipe 50 , Anti-siphonage pipe (1)Connecting soil pipe 50, (2)Connecting waste pipe 40

Traps

• Devices which is connected at the end of the soil pipe or waste pipe to stop the entry of foul gases inside the building is known as trap. • It is a bend pipe in the shape of 'U' which always remain full of water. • The vertical distance between the crown and the dip of the trap is known as water seal. • Generally the water seal varies from 75mm to 100mm. • Water seal is required to prevent entry of foul gas.

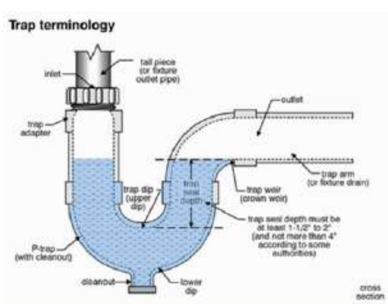
Requirements of a good trap:

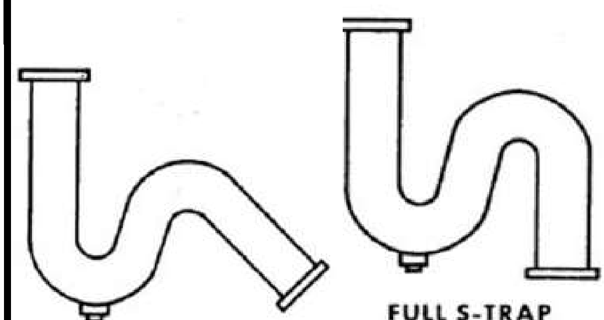
• It should possess adequate water seal at all time. • Non absorbent material • Internal and external surfaces should have smooth finish so that dirt etc. does not stick to it. • Free from any inside projections, angles, contractions, so that flow is not obstructed. • Self cleansing. • Simple in construction, Cheap and readily available. • Should have suitable access for cleaning.

Types of traps

i) P, Q, and S traps

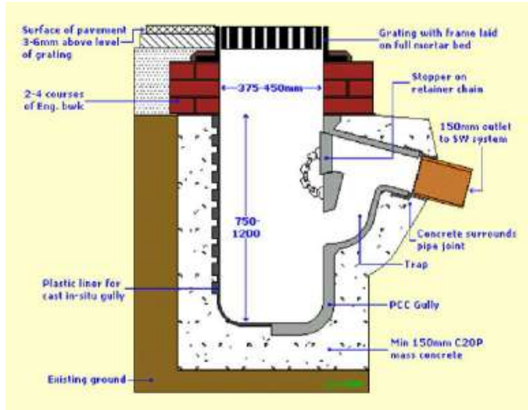
These traps are classified according to their shape. They essentially consist of a U-tube which retains water acting as a seal between the foul gas atmosphere.





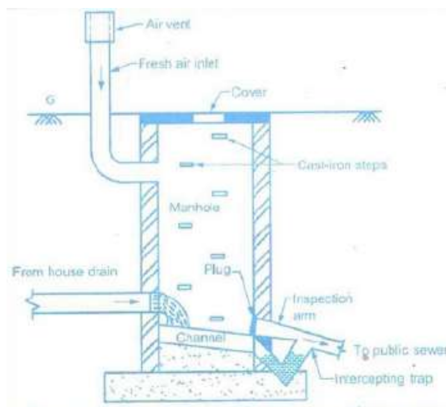
ii) Gully traps

This trap is provided at different places in the drain pipes. Waste water from sinks, bath etc. enters through back inlet and unfoul water from the sweeping of rooms.



iii) An intercepting trap

The sewage from every house goes in street sewers which carry it away from the city. The street sewers contain foul gases in it and if their passage is not checked from street sewers to the house. They may enter in the house drain and pollute the atmosphere. For this purpose a trap in one inspection chamber is provided outside the houses which are called an intercepting trap.



iv) Anti D trap

P, Q and S types of traps may contain large mouth and they easily flushed out. But in this traps full bore of the trap is not interfered by discharge. Shown in

v) Anti siphon trap

These are called re called traps. These traps avoid the connection to vent pipe and reduce the expensive work. Here when water is subjected to the pull due to siphonic action the heavier atmospheric pressure on the inlet side presses the water down and the air can pass from any pass tube B shown in fig. a) water is stored in trough C, when the pressure on both sides becomes equal, the water stored in trough C, falls back in the tube and seals it.

Sanitary fittings

In buildings various types of sanitary fittings are required to collect the waste water. These all fittings can be broadly classified as

• The following sanitary fittings are commonly used in buildings, for efficient collection and removal of wastewater to the house drain. 1. Wash basin 2. Sinks 3. Bath tubes 4. Water closets 5. Urinals 6. Flushing cisterns

Wash basins

• The bowl c is made plain without even a stopper, and has a strainer only. • The stopper and standing overflow are contained in the tube a. • the surplus water escapes through the holes b. Bowls are also made with flushing rims, and the faucets are placed below the top, having only the handles in sight. • The rim of the bowl is thus freed from all obstructions, and the hands of the bather cannot be injured by the nozzles of the faucets.

Sinks

• Normally rectangular basin used in kitchen or laboratory for cleaning utensils and glassware. • Made of glazed earth ware, stainless steel or enameled pressed steel. • Sink has an out let usually of about 40mm dia. • Outlet pipe discharges water over a floor trap.• Mouth of outlet pipe is provided with grating of brass or nickel to prevent entry of coarse solids.

Bath tubs

• For long and luxurious bath • Made of iron or steel coated with enamel, enameled porcelain or of plastic. • May be with parallel sides or with parallel sides or with tapering sides. • It is provided with outlets and outflow pipes, usually 40mm diameter• A trap with proper water seal is used at the outlet. • Conventional sizes of bathtub: –Length 1.7 to 1.85 m –Width 0.7 to 0.75 m –Depth 0.6m

Water Closets (WC)

• A water closet is a sanitary fitting which is designed to receive human excreta directly and convey to the septic tank or underground sewer through a trap. Closet is setup at the floor level and pair of foot rests is provided on both side of the pan. –The trap consists of a hole on the top of the connection to anti-syphonage pipe. –The length of pan varies from 450mm to 675 mm and water seal varies from 50mm to 75mm. –A flushing rim is provided on the top interior surface for flushing the closet with water which may be supplied through the flushing tank, cisterns or direct flush valve.

Oxygen sag curve

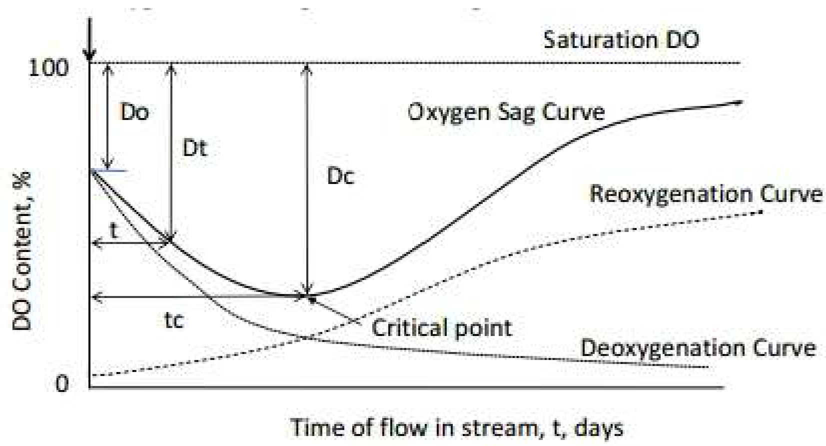
The curve obtained when the concentration of dissolved oxygen in a river into which sewage or some other pollutant has been discharged is plotted against the distance downstream from the sewage outlet (see graph). Samples of water are taken at areas upstream and downstream from the sewage outlet. The presence of sewage reduces the oxygen content of the water and increases the biochemical oxygen demand. This is due to the action of saprotrophic organisms that decompose the organic matter in the sewage and in the process use up the available oxygen

The oxygen sag or oxygen deficit in the stream at any point of time during self purification process is the difference between the saturation DO content and actual DO content at that time.

Oxygen deficit, D = Saturation DO – Actual DO

The saturation DO value for fresh water depends upon the temperature and total dissolved salts present in it; and its value varies from 14.62 mg/L at 0o C to 7.63 mg/L at 30o C, and lower DO at higher temperatures.

The DO in the stream may not be at saturation level and there may be initial oxygen deficit 'Do'. At this stage, when the effluent with initial BOD load Lo, is discharged in to stream, the DO content of the stream starts depleting and the oxygen deficit (D) increases. The variation of oxygen deficit (D) with the distance along the stream, and hence with the time of flow from the point of pollution is depicted by the 'Oxygen Sag Curve' the major point in sag analysis is point of minimum DO, i.e., maximum deficit. The maximum or critical deficit (Dc) occurs at the inflexion points of the oxygen sag curve.



Deoxygenation and Reoxygenation Curves

When wastewater is discharged into the stream, the DO level in the stream goes on depleting. This depletion of DO content is known as deoxygenating. The rate of Deoxygenation depends upon the amount of organic matter remaining (Lt) to be oxidized at any time t, as well as temperature (T) at which reaction occurs. The variation of depletion of DO content of the stream with time is depicted by the deoxygenation curve in the absence of aeration. The ordinates below the Deoxygenation curve indicate the oxygen remaining in the natural stream after satisfying the bio-chemical oxygen demand of oxidizable matter. When the DO content of the stream is gradually consumed due to BOD load, atmosphere supplies oxygen continuously to the water, through the process of re-aeration or Reoxygenation, i.e., along with Deoxygenation, re-aeration is continuous process. The rate of Reoxygenation depends upon: i) Depth of water in the stream: more for shallow depth. ii) Velocity of flow in the stream: less for stagnant water. iii) Oxygen deficit below saturation DO: since solubility rate depends on difference between saturation concentration and existing concentration of DO. iv) Temperature of water: solubility of oxygen is lower at higher temperature and also saturation concentration is less at higher temperature.

Mathematical analysis of Oxygen Sag Curve: Streeter – Phelps equation

The analysis of oxygen sag curve can be easily done by superimposing the rates of Deoxygenation and Reoxygenation as suggested by the Streeter – Phelps analysis. The rate of change in the DO deficit is the sum of the two reactions as explained below:

dDt/ dt = f (Deoxygenation and Reoxygenation)

OR

dDt / dt = K'Lt – R'Dt …. (1)

Where, Dt = DO deficit at any time t,

Lt = amount of first stage BOD remaining at any time t

K' = BOD reaction rate constant or Deoxygenation constant (to the base e)

R' = Reoxygenation constant (to the base e) t = time (in days)

dDt/ dt = rate of change of DO deficit Now,

Where, Lo = BOD remaining at time t = 0 i.e. ultimate first stage BOD Hence,

$$\frac{dDt}{dt} = K' Lo.e^{-K't} - R' Dt$$

$$\frac{dDt}{dt} + R' Dt = K' Lo.e^{-K't}$$

his is first order first degree differential equation and solution of this equation is as under

$$Dt = \frac{K' Lo}{R' - K'}\left[e^{-K't} - e^{-R't}\right] + Do.e^{-R't}$$

Changing base of natural log to 10 the equation can be expressed as:

$$Dt = \frac{KLo}{R - K}\left[10^{-K.t} - 10^{-R.t}\right] + Do.10^{-R.t}$$

Where, K = BOD reaction rate constant, to the base 10

R = Reoxygenation constant to the base 10

Do = Initial oxygen deficit at the point of waste discharge at time t = o

t = time of travel in the stream from the point of discharge = x/u

x = distance along the stream   u = stream velocity

A city discharges 20000 m^3/day of sewage into a river whose rate of flow is 0.7 m^3/sec. Determine D.O. deficit profile for 100 km from the following data:

River	Sewage effluent from STP
5 day B.O.D. at 20^0C = 3.4 mg/l	5 day B.O.D. at 20^0C = 45 mg/l
Temperature 23^0C	Temperature 26^0C
D.O. = 8.2 mg/l	D.O. = 2.0 mg/l

Velocity of mix = 0.25 m/sec, R'=0.4, K' = 0.23

Solution

River discharge = 0.7 m^3/sec, Sewage discharge = 20000/(24x 3600) = 0.231 m^3/sec

BOD of mix= $\frac{(0.7 \times 3.4 + 0.231 \times 45)}{(0.7+0.231)}$ = 13.72 mg/l

D.O. of mix $\frac{(0.7 \times 8.2 + 0.231 \times 2.0)}{(0.7+0.231)}$ = 6.66 mg/l

Temp. of mix $\frac{(0.7 \times 23 + 0.231 \times 26)}{(0.7+0.231)}$ = 23.74 ^0C

Saturation value of D.O. at 23.74 ^0C is 8.57 mg/l

Ultimate B.O.D. $L_t = L_0 (1 - e^{-kxt})$

$13.72 = L_0 (1 - e^{-0.23x5})$

$L_0 = 20.08$ mg/L

Initial D.O. deficit (D_0) = 8.57 - 6.66 = 1.91 mg/L

Deoxygenation and reoxygenation coefficients at 23.74 ^0C temperature

$K_T = K_{20} (\theta)^{T-20}$ Hence, $K_{23.74} = 0.23 (1.047)^{23.74-20} = 0.273$ day^{-1}

$R_T = R_{20} (\theta)^{T-20}$ Hence, $R_{23.74} = 0.40 (1.016)^{23.74-20} = 0.424 \text{ day}^{-1}$

Critical time $t_c = \frac{1}{R'-K'} \log_e \frac{R'}{K'} (1- \frac{D_0 \text{ x } (R'-K')}{K' \text{ x } L0})$

$$= \frac{1}{0.424-0.273} \log_e \frac{0.424}{0.273} (1- \frac{1.91 \text{ x } (0.424-0.273)}{0.273 \text{ x } 20.08})$$

= 2.557 days.

Critical D.O. deficit, $Dc = \frac{K'}{R'} L_0 e^{-K'.tc}$

$$= \frac{0.273}{0.424} 20.08 e^{-0.273 X 2.557}$$

= 6.432 mg/l

Distance at which it occurs = L= velocity x time

= (0.25 m/sec) x (2.557 x 24 x 60 x 60 sec)

= 55231 m = 55.23 km

Similarly time required for mix to reach at 20 km distance, $t_{20km} = \frac{(20 \text{ x } 1000)}{(0.25 \text{ x } 24 \text{ x } 3600)}$

= 0.926 day

And DO deficit at 20 km can be calculated using equation 4

$$Dt = \frac{K' Lo}{R'-K'} \left[e^{-K't} - e^{-R't} \right] + Do.e^{-R't}$$

Where, K' = 0.273 d^{-1}, R' = 0.424 d^{-1}, Do = 1.91 mg/L and Lo = 20.08 mg/L and t = 0.926 day

Hence, DO deficit at 20 km = 4.970 mg/L

Similarly DO deficit at 40 km (i.e. t = 1.852 days) = 6.211 mg/L

and DO deficit at 80 km (i.e., t = 3.704 days) = 6.056 mg/L

and DO deficit at 100 km (i.e., t = 4.63 days) = 5.427 mg/L

The DO deficit at different points along length of river is as below:

Distance in km	Time in days	DO deficit, mg/L	DO, mg/L
0	0	1.91	6.66
20	0.926	4.97	3.6
40	1.852	6.211	2.359
55.23	2.557	6.432	2.138
80	3.704	6.056	2.514
100	4.63	5.427	3.143

Stabilization Ponds

- The ***stabilization ponds*** are open flow through basins specifically designed and constructed to treat sewage and biodegradable industrial wastes. They provide long detention periods extending from a few to several days.
- Pond systems, in which oxygen is provided through mechanical aeration rather than algal photosynthesis, are called *aerated lagoons*.
- Lightly loaded ponds used as tertiary step in waste treatment for polishing of secondary effluents and removal of bacteria are called ***maturation ponds***.

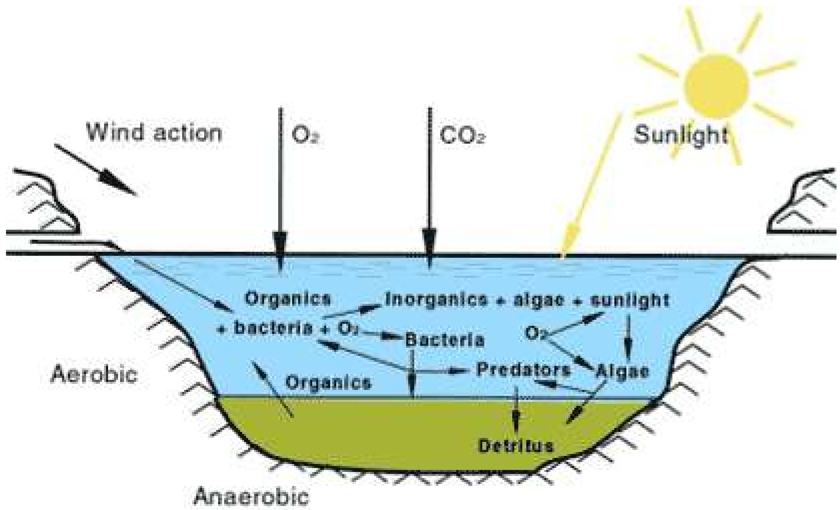
Classification of Stabilization Ponds

Stabilization ponds may be aerobic, anaerobic or facultative.

- ***Aerobic ponds*** are shallow ponds with depth less than 0.5 m and BOD loading of 40-120 kg/ha.d so as to maximize penetration of light throughout the liquid depth. Such ponds develop intense algal growth.
- ***Anaerobic ponds*** are used as pretreatment of high strength wastes with BOD load of 400-3000 kg/ha.d Such ponds are constructed with a depth of 2.5-5m as light penetration is unimportant.
- ***Facultative pond*** functions aerobically at the surface while anaerobic conditions prevail at the bottom. They are often about 1 to 2 m in depth. The aerobic layer acts as a good check against odour evolution from the pond.

Mechanism of Purification

The functioning of a facultative stabilization pond and symbiotic relationship in the pond are shown below. Sewage organics are stabilized by both aerobic and anaerobic reactions. In the top aerobic layer, where oxygen is supplied through algal photosynthesis, the non-settleable and dissolved organic matter is oxidized to CO_2 and water. In addition, some of the end products of partial anaerobic decomposition such as volatile acids and alcohols, which may permeate to upper layers are also oxidized periodically. The settled sludge mass originating from raw waste and microbial synthesis in the aerobic layer and dissolved and suspended organics in the lower layers undergo stabilization through conversion to methane which escapes the pond in form of bubbles.



Factors Affecting Pond Reactions

Various factors affect pond design:

- Waste water characteristics and fluctuations.
- environmental factors (solar radiation, light, temperature)
- algal growth patterns and their diurnal and seasonal variation)
- Bacterial growth patterns and decay rates.
- Solids settlement, gasification, upward diffusion, sludge accumulation.

Oxidation pond

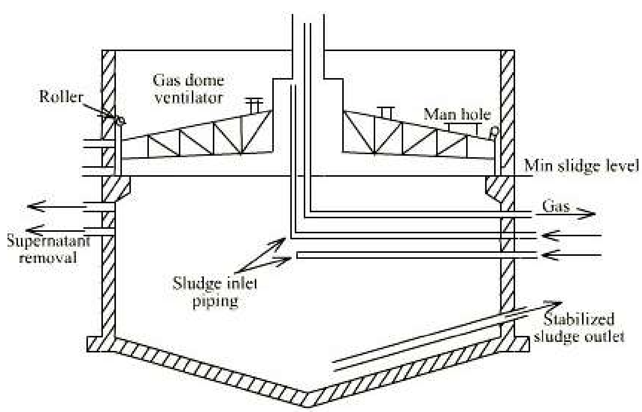
Oxidation Ponds are also known as stabilization ponds or lagoons. They are used for simple secondary treatment of sewage effluents. Within an oxidation pond heterotrophic bacteria degrade organic matter in the sewage which results in production of cellular material and minerals. The production of these supports the growth of algae in the oxidation pond. Growth of algal populations allows further decomposition of the organic matter by producing oxygen. The production of this oxygen replenishes the oxygen used by the heterotrophic bacteria. Typically oxidation ponds need to be less than 10 feet deep in order to support the algal growth. In addition, the use of oxidation ponds is largely restricted to warmer climate regions because they are strongly influenced by seasonal temperature changes. Oxidation ponds also tend to fill, due to the settling of the bacterial and algal cells formed during the decomposition of the sewage. Overall, oxidation ponds tend to be inefficient and require large holding capacities and long retention times. The degradation is relatively slow and the effluents containing the oxidized products need to be periodically removed from the ponds.

Sludge digestion tank

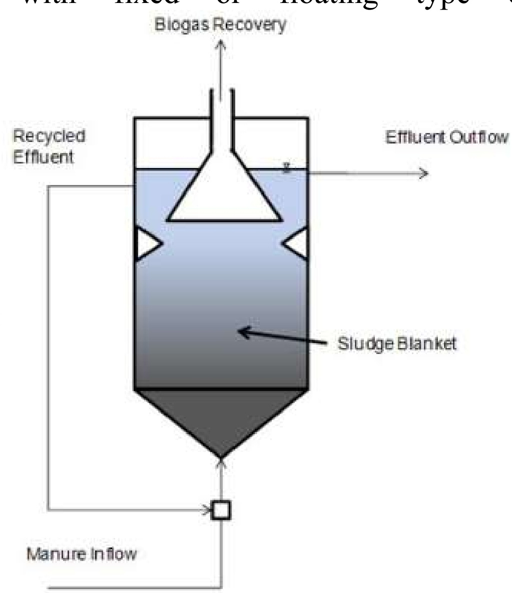
Sludge digestion involves the treatment of highly concentrated organic wastes in the absence of oxygen by anaerobic bacteria. The anaerobic treatment of organic wastes resulting in the production of carbon dioxide and methane, involves two distinct stages. In the first stage, referred to as "***acid fermentation***", complex waste components, including fats, proteins, and polysaccharides are first hydrolyzed by a heterogeneous group of facultative and anaerobic bacteria. These bacteria then subject the products of hydrolysis to fermentations, □-oxidations, and other metabolic processes leading to the formation of simple organic compounds, mainly short-chain (volatile) acids and alcohols. However in the second stage, referred to as "***methane fermentation***", the end products of the first stage are converted to gases (mainly methane and carbon dioxide) by several different species of strictly anaerobic bacteria.

The bacteria responsible for acid fermentation are relatively tolerant to changes in pH and temperature and have a much higher rate of growth than the bacteria responsible for methane fermentation. If the pH drops below 6.0, methane formation essentially ceases, and more acid accumulates, thus bringing the digestion process to a standstill. As a result, methane fermentation is generally assumed to be the rate limiting step in anaerobic wastewater treatment. The methane bacteria are highly active in mesospheric (27-43°C) with digestion period of four weeks and thermophilic range (35-40°C) with digestion period of 15-18 days. But themophilic range is not practiced because of odour and operational difficulties.

Digestion Tanks or Digesters: A sludge digestion tank is a RCC or steel tank of cylindrical shape with hopper bottom and is covered with fixed or floating type of roofs.



Anaerobic sludge digester



Design Details

Generally digesters are designed to treat for a capacity up to 4 MLD.

1. Tank sizes are not less than 6 m diameter and not more than 55 m diameter.
2. Liquid depth may be 4.5 to 6 m and not greater than 9 m.
3. The digester capacity may be determined from the relationship

$$V = [V_f - 2/3(V_f - V_d)]t_1 + V_d t_2$$

Where V = capacity of digester in m^3, V_f = volume of fresh sludge m^3/d, V_d = volume of daily digested sludge accumulation in tank m^3/d, t_1= digestion time in days required for digestion, d, and t_2 = period of digested sludge storage.

Gas Collection

The amount of sludge gas produced varies from 0.014 to 0.028 m^3per capita. The sludge gas is normally composed of 65% methane and 30% carbon dioxide and remaining 5% of nitrogen and other inert gases, with a calorific value of 5400 to 5850 kcal/m^{3}.

Soak pits

The soak pit, consisting basically of a simple pit (generally approximately 1 m3), should be between 1.5 and 4 m deep, but as a rule of thumb, never less than 2 m above the groundwater table. It should be located at a safe distance from a drinking water source (ideally more than 30 m). The soak pits should be kept away from high-traffic areas so that the soil above and around it is not compacted. It can be left empty and lined with a porous material to provide support and prevent collapse, or left unlined and filled with coarse rocks and gravel. The rocks and gravel will prevent the walls from collapsing, but will still provide adequate space for the wastewater. In both cases, a layer of sand and fine gravel should be spread across the bottom to help disperse the flow. To allow for future access, a removable (preferably concrete) lid should be used to seal the pit until it needs to be maintained.

A well-sized soak pit should last between 3 and 5 years without maintenance. To extend the life of a soak pit, care should be taken to ensure that the effluent has been clarified and/or filtered to prevent the excessive build-up of solids.

The soak pit should be kept away from high-traffic areas so that the soil above and around it is not compacted. Particles and biomass will eventually clog the pit and it will need to be cleaned or moved. When the performance of the soak pit deteriorates, the material inside the soak pit can be excavated and refilled.

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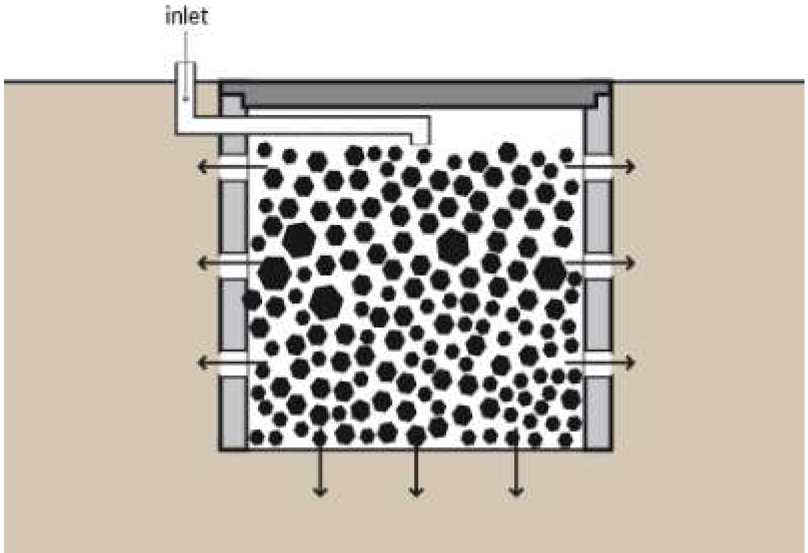


Septic tank

A **septic tank** is a key component of a **septic system**, a small-scale sewage treatment system common in areas that lack connection to main sewage pipes provided by local governments or private corporations. Other components may include pumps, alarms, sand filters, and clarified liquid effluent disposal methods such as a septic drain field, ponds, natural stone fiber filter plants or peat moss beds

The term "septic" refers to the anaerobic bacterial environment that develops in the tank which decomposes or mineralizes the waste discharged into the tank. Septic tanks can be coupled with other onsite wastewater treatment units such as biofilters or aerobic systems involving artificially forced aeration.

A septic tank consists of one or more concrete or plastic tanks of between 4000 and 7500 liters (1,000 and 2,000 gallons); one end is connected to an inlet wastewater pipe and the other to a septic drain field. Generally these pipe connections are made with a T pipe, allowing liquid to enter and exit without disturbing any crust on the surface. Today, the design of the tank usually incorporates two chambers, each equipped with a manhole cover, and separated by a dividing wall with openings located about midway between the floor and roof of the tank.

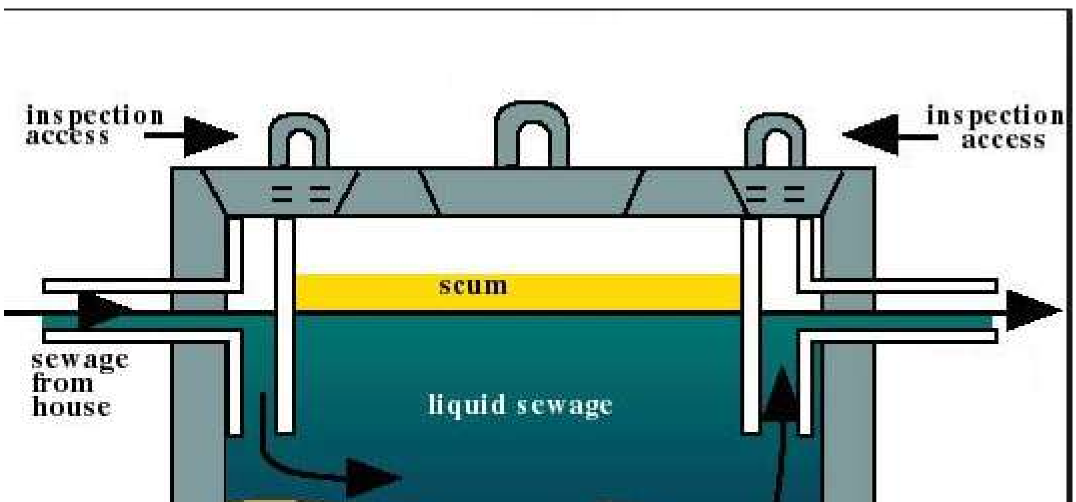
Wastewater enters the first chamber of the tank, allowing solids to settle and scum to float. The settled solids are anaerobically digested, reducing the volume of solids. The liquid component flows through the dividing wall into the second chamber, where further settlement takes place. The excess liquid, now in a relatively clear condition, then drains from the outlet into the septic drain field, also referred to as a leach field, drain field or seepage field, depending upon locality. A percolation test is required prior to installation to ensure the porosity of the soil is adequate to serve as a drain field.

The remaining impurities are trapped and eliminated in the soil, with the excess water eliminated through percolation into the soil, through evaporation, and by uptake through the root system of plants and eventual transpiration or entering groundwater or surface water. A piping network, often laid in a stone-filled trench (see weeping tile), distributes the wastewater throughout the field with multiple drainage holes in the network. The size of the drain field is proportional to the volume of wastewater and inversely proportional to the porosity of the drainage field. The entire septic system can operate by gravity alone or, where topographic considerations require, with inclusion of a lift pump. Certain septic tank designs include siphons or other devices to increase the volume and velocity of outflow to the drainage field. These help to fill the drainage pipe more evenly and extend the drainage field life by preventing premature clogging.

An Imhoff tank is a two-stage septic system where the sludge is digested in a separate tank. This avoids mixing digested sludge with incoming sewage. Also, some septic tank designs have a second stage where the effluent from the anaerobic first stage is aerated before it drains into the seepage field.

A properly designed and normally operating septic system is odor-free and, besides periodic inspection and emptying of the septic tank, should last for decades with minimal maintenance.

A well designed and maintained concrete, fiberglass, or plastic tank should last about 50 years



Waste that is not decomposed by the anaerobic digestion must eventually be removed from the septic tank. Otherwise the septic tank fills up and wastewater containing undecomposed material discharges directly to the drainage field. Not only is this detrimental for the environment but, if the sludge overflows the septic tank into the leach field, it may clog the leach field piping or decrease the soil porosity itself, requiring expensive repairs.

When a septic tank is emptied, the accumulated sludge (septage, also known as fecal sludge is pumped out of the tank by a vacuum truck. How often the septic tank must be emptied depends on the volume of the tank relative to the input of solids, the amount of indigestible solids, and the ambient temperature (because anaerobic digestion occurs more efficiently at higher temperatures), as well as usage, system characteristics and the requirements of the relevant authority. Some health authorities require tanks to be emptied at prescribed intervals, while others leave it up to the decision of an inspector. Some systems require pumping every few years or sooner, while others may be able to go 10–20 years between pumping. An older system with an undersized tank that is being used by a large family will require much more frequent pumping than a new system used by only a few people. Anaerobic decomposition is rapidly restarted when the tank is refilled.

Assignment-Cum-Tutorial Questions

A. Questions testing the remembering / understanding level of students

I) Objective Questions

1. B.O.D/C.O.D is always ___________________.
2. One pipe system adoptable to___________________.
3. Standard B.O.D at _______________________.TEMP
4. Slope of oxygenation curve varies from ---------to ------------in oxygen sag curve
5. In sludge digestion tank in ----------and----------stages organic matter will be digested,.
6. Organic matter in the septic tank decomposed by the _____________ process.
7. Soak pits should keep away from_____________.

II) Descriptive Questions

1. What is meant by oxygen demand of sewage?
2. What is meant by ultimate disposal of sewage?
3. What are the systems of plumbing for house drainage?
4. Note down the components in house drainage system?
5. What is the principle of sludge digestion tank?
6. What is the principle of septic tank?
7. Draw oxygen sag curve for disposal of sewage in flowing streams?

B. Question testing the ability of students in applying the concepts.

I) Multiple Choice Questions

1. Aerobic bacteria
   a. consume organic matter as their food
   b. flourish in the presence of free oxygen.
   c. oxidize organic matter in the sewage
   d. all

2. The rate of accumulation of sludge in septic tanks is recommended as ---- lit/person/month
   a. 30 lit/person/year b. 25 lit/person/year c. 25 lit/person/month d. 30 lit/person/month

3. An inverted siphon is generally designed for
   a. One pipe   b. two pipe   c. three pipe   d. four pipe

4. If 2% solution of a sewage sample is incubated for 5 days at 20 degrees centigrade and depletion of oxygen was found to be 5 ppm, B.O.D. of the sewage is
   a. 225ppm   b. 250ppm   c. 200ppm   d. none of these

5. For the survival of fish in a river stream, the minimum dissolved oxygen is prescribed
   a. 3ppm   b. 4ppm   c. 5ppm   d. 10ppm
   b.

6. The process of nutrient enrichment is termed as
   a. Eutrification   b. limiting nutrients   c. enrichment   d. schistosomiasis

7. Lagoons maybe characterized as
   a. aerated   b. anaerobic   c. facultative   d. all of these

II) Descriptive Questions

1. Derive B.O.D. Equation.
2. Briefly explain one pipe and two pipe systems of plumbing?
3. List 4 traps using in house drainage system and briefly explain them?
4. Design a septic tank for the population of 300 members in a colony. And make your assumption clearly.
5. Explain oxygen sag curve with neat sketch.
6. Briefly explain about aerobic and anaerobic ponds?
7. List out sanitary fittings and explain about them?

C. Questions testing the analyzing / evaluating the ability of students

1) For cultural event such as Krishna pushkaram many temporary toilets had built near the river. Investigate how the sewage from these makeshift lavatories is handled and comment if it is satisfactory. If not suggest alternative.
2) Find out what percent of the sewage generated in urban India is treated before disposal
3) Workout the sewage generated in the new academic block (CIVIL and MECHANICAL department of GEC). State your assumption clearly and design a septic tank to treat this water before disposal.
4) Derive streeter-phelps equation for oxygen sag curve in a flowing water body that receives municipal sewage.
5) What is sewage farming? Explain its merits and demerits.

D. GATE/Competitive oriented questions

1. Fresh water lakes are most often limited by
   a. nitrogen
   b. phosphorus
   c. carbon
   d. none of the above
2. the chemical oxygen demand measures the
   a. amount of oxygen required for growth of micro organism in water
   b. amount of oxygen that would be removed from the water in order to oxidize pollution
   c. amount of oxygen required to oxidize the calcium present in waste water
   d. none of these
3. BOD stands for
   a. Bio chemical oxygen demand
   b. British oxygen demand
   c. British oxygen depletion
   d. Biological oxygen depletion
4. The methods used for biological treatment are
   a. lagoon
   b. activated sludge process
   c. oxidation ditches
   d. all of the above
5. colliform bacteria in water is an indication of the presence of
   a. radioactive wastes
   b. excess fertilizer
   c. decaying animals and plants
   d. human feces
6. in country area untreated sewage is pumped into tanks is known as
   a. septic tank
   b. sewage tank

c. grit tank
d. sludge tank

7. in the self cleaning process that takes place in a stream, BOD reduction in the zones of degradation is principally caused by
   a. bacterial action
   b. turbidity
   c. temperature change
   d. settling

ENVIRONMENTAL ENGINEERING
UNIT V
WASTE WATER TREATMENT

Objective: This unit is about designing a suitable wastewater treatment plant.

That is to say, what actually happens within the four walls of the treatment plant. The treatment operations are conveniently categorised as **Preliminary, Primary, Secondary** and **Tertiary.** The unit details the operations, their design considerations and applications.

Syllabus
Waste Water Treatment
Layout and general outline of various units in a waste water treatment plant
Primary treatment - Design of screens – grit chambers – skimming tanks –
Secondary treatment - Sedimentation tanks –
Introduction to biological treatment – Trickling filters – standard and high rate,
Activated sludge process.

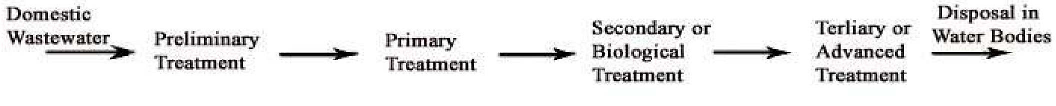
Learning Outcomes: After completion of this unit, the student will be able to

> explain the primary, secondary treatment units in a sewage treatment plant
> distinguish between physical, chemical, biological treatment methods
> solve problems on attached growth and suspended growth process design problems

Wastewater (sewage) Treatment

The raw sewage must be treated before it is discharged into the river stream. The extent of treatment required to be given depends not only upon the characteristics and quality of the sewage but also upon the sink of disposal, its quality and capacity to tolerate the impurities present in the sewage effluents without itself getting potentially polluted.

The layout of conventional wastewater treatment plant is as follows:



Siting and Hydraulics of Wastewater Treatment Plant

Plant layout is the arrangement of designed treatment units on the selected site. The components that need to be included in a treatment plant, should be so laid out as to optimize land requirement, minimize lengths of interconnecting pipes and pumping heads. Access for sludge and chemicals transporting, and for possible repairs, should be provided in the layout.

Siting is the selection of site for treatment plant based on features as character, topography, and shoreline. Site development should take the advantage of the existing site topography. The following principles are important to consider:

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UNIT V

1.A site on a side-hill can facilitate gravity flow that will reduce pumping requirements and locate normal sequence of units without excessive excavation or fill.

2.When landscaping is utilized it should reflect the character of the surrounding area. Site development should alter existing naturally stabilized site contours and drainage as little as possible.

3.The developed site should be compatible with the existing land uses and the comprehensive development plan.

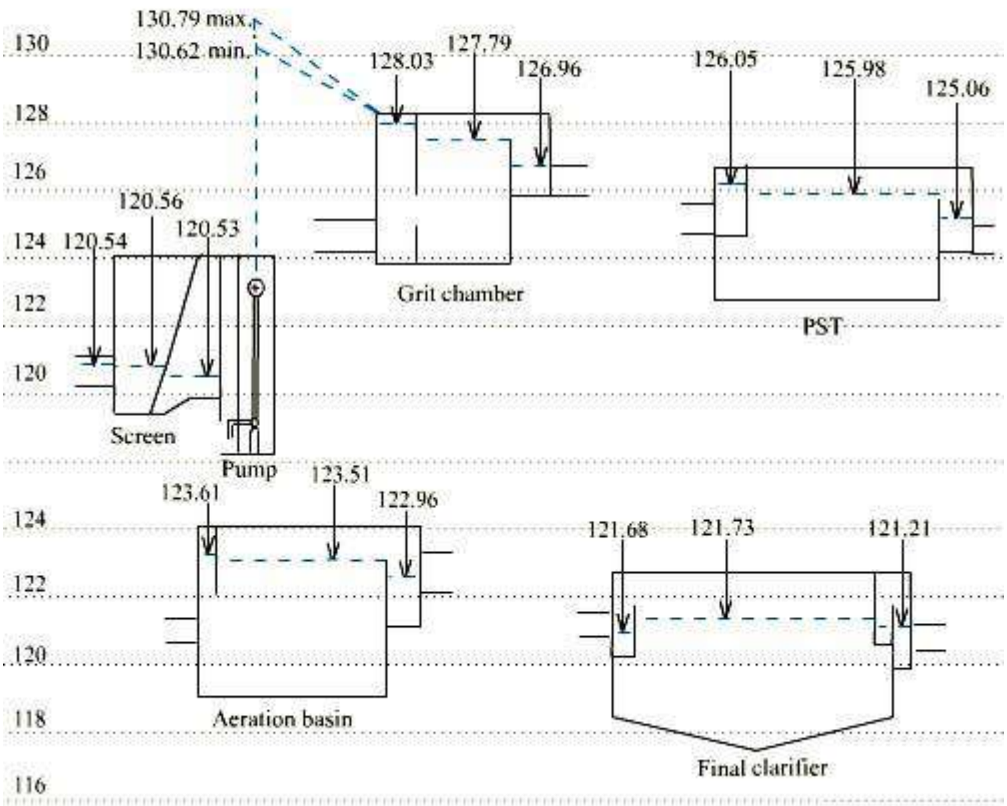
Treatment Plant Hydraulics.

Hydraulic profile is the graphical representation of the hydraulic grade line through the treatment plant. If the high water level in the receiving water is known, this level is used as a control point, and the head loss computations are started backward through the plant. The **total available head** at the treatment plant is the difference in water surface elevations in the interceptor and the water surface elevation in the receiving water at high flood level. If the total available head is less than the head loss through the plant, flow by gravity cannot be achieved. In such cases pumping is needed to raise the head so that flow by gravity can occur.

There are many basic principles that must be considered when preparing the hydraulic profile through the plant. Some are listed below:

1. The hydraulic profiles are prepared at peak and average design flows and at minimum initial flow.
2. The hydraulic profile is generally prepared for all main paths of flow through the plant.
3. The head loss through the treatment plant is the sum of head losses in the treatment units and the connecting piping and appurtenances.
4. The head losses through the treatment unit include the following:
    a) Head losses at the influent structure.
    b) Head losses at the effluent structure.
    c) Head losses through the unit.
    d) Miscellaneous and free fall surface allowance.
5. The total loss through the connecting pipings, channels and appurtenances is the sum of following:
    a) Head loss due to entrance.
    b) Head loss due to exit.
    c) Head loss due to contraction and enlargement.
    d) Head loss due to friction.
    e) Head loss due to bends, fittings, gates, valves, and meters.
    f) Head required over weir and other hydraulic controls.
    g) Free-fall surface allowance.

Typical Hydraulic Profile through treatment facility



Indian Standards for discharge of sewage in surface waters are given in the table below.

Parameter	**Tolerance limit *for Discharge of Sewage in Surface Water Sources***
BOD_5	20 mg/L
TSS	30 mg/L

The unit operations and processes commonly employed in domestic wastewater treatment, their functions and units used to achieve these functions are given in the following table:

Unit Operations/Processes, Their Functions and Units Used for Wastewater Treatment;

Operations/Processes	**Functions**	**Treatment Devices**
Screening	Removal of large floating, suspended and settleable solids	Bar racks and screens of various description
Grit Removal	Removal of inorganic suspended solids	Grit chamber
Primary Sedimentation	Removal of organic/inorganic settleable solids	Primary sedimentation tank
Aerobic Biological Suspended Growth Process	Conversion of colloidal, dissolved and residual suspended organic matter into settleable biofloc and stable inorganics	Activated sludge process units and its modifications, Waste stabilisation ponds,

		Aerated lagoons
Aerobic Biological Attached Growth Process	same as above	Trickling filter, Rotating biological contactor
Anaerobic biological growth processes	Conversion of organic matter into CH_4 & CO_2 and relatively stable organic residue	Anaerobic filter, Fluid bed submerged media anaerobic reactor, Upflow anaerobic sludge blanket reactor, Anaerobic rotating biological contactor
Anaerobic Stabilization of Organic Sludges	same as above	Anaerobic digestor

Screening

A screen is a device with openings for removing bigger suspended or floating matter in sewage which would otherwise damage equipment or interfere with satisfactory operation of treatment units.

Types of Screens

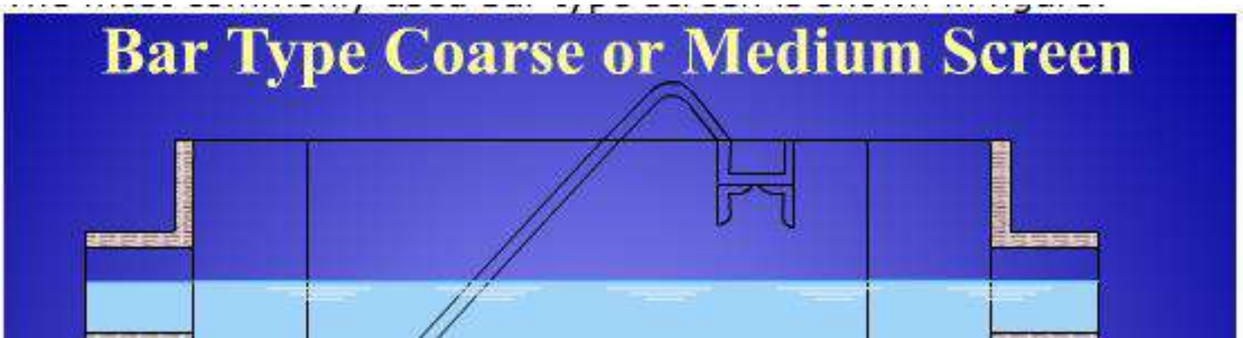
Coarse Screens: Coarse screens also called racks, are usually bar screens, composed of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows. Bar screens with relatively large openings of 75 to 150 mm are provided ahead of pumps, while those ahead of sedimentation tanks have smaller openings of 50 mm.

Bar screens are usually hand cleaned and sometimes provided with mechanical devices. These cleaning devices are rakes which periodically sweep the entire screen removing the solids for further processing or disposal. Hand cleaned racks are set usually at an angle of 45° to the horizontal to increase the effective cleaning surface and also facilitate the raking operations. Mechanical cleaned racks are generally erected almost vertically. Such bar screens have openings 25% in excess of the cross section of the sewage channel.

Medium Screens: Medium screens have clear openings of 20 to 50 mm. Bars are usually 10 mm thick on the upstream side and taper slightly to the downstream side. The bars used for screens are rectangular in cross section usually about 10 x 50 mm, placed with larger dimension parallel to the flow.

Fine Screens: Fine screens are mechanically cleaned devices using perforated plates, woven wire cloth or very closely spaced bars with clear openings of less than 20 mm. Fine screens are not normally suitable for sewage because of clogging possibilities.

The most commonly used bar type screen is shown in figure:



A photograph of a bar screen is given hereafter.

Velocity

The velocity of flow ahead of and through the screen varies and affects its operation. The lower the velocity through the screen, the greater is the amount of screenings that would be removed from sewage. However, the lower the velocity, the greater would be the amount of solids deposited in the channel. Hence, the design velocity should be such as to permit 100% removal of material of certain size without undue depositions. Velocities of 0.6 to 1.2 mps through the open area for the peak flows have been used satisfactorily. Further, the velocity at low flows in the approach channel should not be less than 0.3 mps to avoid deposition of solids.

Head loss

Head loss varies with the quantity and nature of screenings allowed to accumulate between cleanings. The head loss created by a clean screen may be calculated by considering the flow and the effective areas of screen openings, the latter being the sum of the vertical projections of the openings. The head loss through clean flat bar screens is calculated from the following formula:

$$h = 0.0729 (V^2 - v^2)$$

where, h = head loss in m

V = velocity through the screen in mps

v = velocity before the screen in mps

Another formula often used to determine the head loss through a bar rack is Kirschmer's equation:

$h = b\ (W/b)^{4/3}\ h_v \sin q$

where h = head loss,m

b = bar shape factor (2.42 for sharp edge rectangular bar, 1.83 for rectangular bar with semicircle upstream, 1.79 for circular bar and 1.67 for rectangular bar with both u/s and d/s face as semicircular).

W = maximum width of bar u/s of flow, m

b = minimum clear spacing between bars, m

h_v = velocity head of flow approaching rack, m = $v^2/2g$

q = angle of inclination of rack with horizontal

The head loss through fine screen is given by

h = (1/2g) (Q/CA)

where, h = head loss, m
Q = discharge, m^3/s
C = coefficient of discharge (typical value 0.6)
A = effective submerged open area, m^2

The quantity of screenings depends on the nature of the wastewater and the screen openings.

Equalisation Tanks

The equalization tanks are provided (i) to balance fluctuating flows or concentrations, (ii) to assist self neutralization, or (iii) to even out the effect of a periodic "slug" discharge from a batch process.

Types of Equalization Tanks

Equalization tanks are generally of three types:

1. Flow through type
2. Intermittent flow type
3. Variable inflow/constant discharge type

The simple flow through type equalization tank is mainly useful in assisting self neutralization or evening out of fluctuating concentrations, not for balancing of flows since a flow through type tank once filled, gives output equal to input.

Flow balancing and self-neutralization are both achieved by using two tanks, intermittently one after another. One tank is allowed to fill up after which it is checked for pH (or any other parameter) and then allowed to empty out. The second tank goes through a similar routine. Intermittent flow type tanks are economic for small flows from industries.

When flows are large an equalization tank of such a size may have to be provided that inflow can be variable while outflow is at a constant rate, generally by a pump. The capacity required is determined from a plot of the cumulative inflow and a plot of the constant rate outflow and measuring the gaps between the two plots. A factor of safety may be applied if desired.

Generally, detention time vary from 2 to 8 hours but may be even 12 hours or more in some cases. When larger detention times are required, the equalization unit is sometimes provided in the form of facultative aerated lagoon.

Grit Chambers

Grit chambers are basin to remove the inorganic particles to prevent damage to the pumps, and to prevent their accumulation in sludge digestors.

Types of Grit Chambers

Grit chambers are of two types: mechanically cleaned and manually cleaned. In mechanically cleaned grit chamber, scraper blades collect the grit settled on the floor of the grit chamber. The grit so collected is elevated to the ground level by several mechanisms such as bucket elevators, jet pump and air lift. The grit washing mechanisms are also of several designs most of which are agitation devices using either water or air to produce washing action. Manually cleaned grit chambers should be cleaned atleast once a week. The simplest method of cleaning is by means of shovel.

Aerated Grit Chamber

An aerated grit chamber consists of a standard spiral flow aeration tank provided with air diffusion tubes placed on one side of the tank. The grit particles tend to settle down to the bottom of the tank at rates dependant upon the particle size and the bottom velocity of roll of the spiral flow, which in turn depends on the rate of air diffusion through diffuser tubes and shape of aeration tank. The heavier particles settle down whereas the lighter organic particles are carried with roll of the spiral motion.

Principle of Working of Grit Chamber

Grit chambers are nothing but like sedimentation tanks, designed to separate the intended heavier inorganic materials (specific gravity about 2.65) and to pass forward the lighter organic materials. Hence, the flow velocity should neither be too low as to cause the settling of lighter organic matter, nor should it be too high as not to cause the settlement of the silt and grit present in the sewage. This velocity is called "differential sedimentation and differential scouring velocity". The scouring velocity determines the optimum flow through velocity. This may be explained by the fact that the critical velocity of flow 'vc' beyond which particles of a certain size and density once settled, may be again introduced into the stream of flow. It should always be less than the scouring velocity of grit particles. The critical velocity of scour is given by Schield's formula:

V = 3 to 4.5 (g(Ss - 1)d)1/2

A horizontal velocity of flow of 15 to 30 cm/sec is used at peak flows. This same velocity is to be maintained at all fluctuation of flow to ensure that only organic solids and not the grit is scoured from the bottom.

Types of Velocity Control Devices

1. A sutro weir in a channel of rectangular cross section, with free fall downstream of the channel.
2. A parabolic shaped channel with a rectangular weir.
3. A rectangular shaped channel with a parshall flume at the end which would also help easy flow measurement.

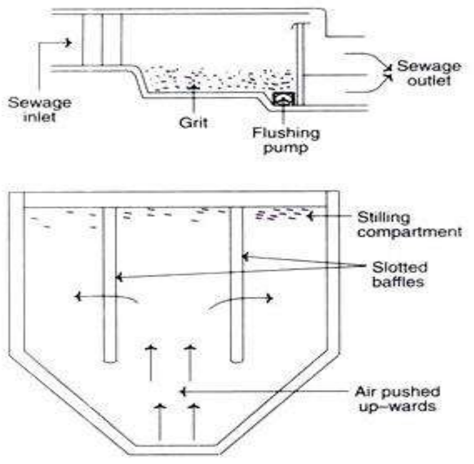
Design of Grit Chambers

Grit chamber is aimed to capture grit from waste water. If grit is not removed from waste water, it will increase wear & tear, abrasion of mechanical equipment, pipes etc. It causes reduction of life of the mechanical components.

Composition of grit:

Grit is composition of inorganic and organic matter.

Eg: sand, silt, clay, broken glass pieces, metal fragments, tea grounds, egg shells, bone chips, seeds etc.



Grit chamber

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Grit chamber is a long narrow rectangular channel with increased c/s dimensions which decelerate flow velocity there by allowing grit to settle. To maintain constant flow velocity throughout its operation irrespective of the flow fluctuations a velocity control device is provided. We call it as proportional flow weir provided at the outlet of the chamber. An increase in flow velocity leads to scouring of settled grit and decrease in flow velocity leads to settling of other particles along with grit. Therefore maintaining constant flow velocity is the main feature of grit chambers.

Settling Velocity

The settling velocity of discrete particles can be determined using appropriate equation depending upon Reynolds number.

- Stoke's law: $v = \frac{g(S_s-1)d^2}{18u}$

Stoke's law holds good for Reynolds number,Re below 1.

$$Re = \frac{vd}{u}$$

For grit particles of specific gravity 2.65 and liquid temperature at 10°C, $u=1.01 \times 10^{-6} m^2/s$. This corresponds to particles of size less than 0.1 mm.

- Transition law: The design of grit chamber is based on removal of grit particles with minimum size of 0.15 mm and therefore Stoke's law is not applicable to determine the settling velocity of grit particles for design purposes.

$$v^2 = \frac{4g(r_p-r)d}{3\,C_D r}$$

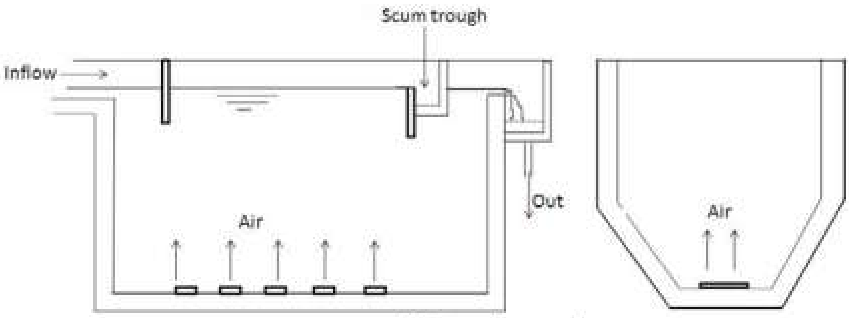
where, CD= drag coefficient Transition flow conditions hold good for Reynolds number,Re between 1 and 1000. In this range CD can be approximated by

$$C_D = \frac{18.5}{Re^{0.6}} = \frac{18.5}{(vd/u)^{0.6}}$$

Substituting the value of CD in settling velocity equation and simplifying, we get

$$v = [0.707(S_s-1)d^{1.6} u^{-0.6}]^{0.714}$$

Skimming tank or Rotational chamber



Skimming tank

The floating solid materials such as soap, vegetables, debris, fruit skins, pieces of corks, etc. and oil and grease are removed from the wastewater in skimming tanks. A skimming tank is a chamber designed so that floating matter rises and remains on surface of the wastewater until removed, while the liquid flows continuously through outlet or partition below the water lines. The detention time in skimming tank is 3 minutes. To prevent heavy solids from settling at the bed, compressed air is blown through the diffusers placed in the floor of the tank. Due to compress air supply, the oily matters rise upward and are collected in the side trough, from where they are removed. In conventional sewage treatment plant separate skimming tank is not used and these materials are removed by providing baffle ahead of the effluent end of the primary sedimentation tank.

Primary Sedimentation

Primary sedimentation in a municipal wastewater treatment plant is generally plain sedimentation without the use of chemicals. In treating certain industrial wastes chemically aided sedimentation may be involved. In either case, it constitutes flocculent settling, and the particles do not remain discrete as in the case of grit, but tend to agglomerate or coagulate during settling. Thus, their diameter keeps increasing and settlement proceeds at an over increasing velocity. Consequently, they trace a curved profile.

The settling tank design in such cases depends on both surface loading and detention time.

Long tube settling tests can be performed in order to estimate specific value of surface loading and detention time for desired efficiency of clarification for a given industrial wastewater using recommended methods of testing. Scale-up factors used in this case range from 1.25 to 1.75 for the overflow rate, and from 1.5 to 2.0 for detention time when converting laboratory results to the prototype design.

For primary settling tanks treating municipal or domestic sewage, laboratory tests are generally not necessary, and recommended design values given in table may be used. Using an appropriate value of surface loading from table, the required tank area is computed. Knowing the average depth, the detention time is then computed. Excessively high detention time (longer than 2.5 h) must be avoided especially in warm climates where anaerobicity can be quickly induced. Design parameters for settling tank

Types of settling	Overflow rate m3m2/day		Solids loading kg/m2/day		Depth	Detention time
	Average	Peak	Average	Peak		
Primary settling only	25-30	50-60	-	-	2.5-3.5	2.0-2.5
Primary settling followed by secondary treatment	35-50	60-120	-	-	2.5-3.5	
Primary settling with activated sludge return	25-35	50-60	-	-	3.5-4.5	-
Secondary settling for trickling filters	15-25	40-50	70-120	190	2.5-3.5	1.5-2.0
Secondary settling for activated sludge (excluding extended aeration)	15-35	40-50	70-140	210	3.5-4.5	-
Secondary settling for extended aeration	8-15	25-35	25-120	170	3.5-4.5	-

Classification of Micro organisms

1. Nutritional Requirements: On the basis of chemical form of carbon required, microorganisms are classified as
   a. Autotrophic: organisms that use CO_2 or HCO_3^- as their sole source of carbon.
   b. Heterotrophic: organisms that use carbon from organic compounds.

Energy Requirements: On the basis of energy source required, microorganisms are classified as

. Phototrophs: organisms that use light as their energy source.
   a. Chemotrophs: organisms that employ oxidation-reduction reactions to provide energy. They are further classified on the basis of chemical compounds oxidized (i.e., electron donor)
      i. Chemoorganotrophs: Organisms that use complex organic molecules as their electron donor.
      ii. Chemoautotrophs: Organisms that use simple inorganic molecules such as hydrogen sulfide or ammonia as their electron donor.

Temperature Range: On the basis of temperature range within which they can proliferate, microorganisms are classified as

. Psychrophilic: organisms whose growth is optimum within 15 to 30°C.
   a. Mesophilic: organisms whose growth is optimum within 30 to 45°C.
   b. Thermophilic: organisms whose growth is optimum within 45 to 70°C.

Oxygen Requirements: On the basis of oxygen requirement microorganisms are classified as

   . Aerobes: organisms that use molecular oxygen as electron acceptor.
   a. Anaerobes: organisms that use some molecule other than molecular oxygen as electron acceptor.
   b. Facultative organisms : organisms that can use either molecular oxygen or some other chemical compound as electron acceptor.

Growth Pattern of Micro organisms

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When a small number of viable bacterial cells are placed in a close vessel containing excessive food supply in a suitable environment, conditions are established in which unrestricted growth takes place. However, growth of an organism do not go on indefinitely, and after a characteristic size is reached, the cell divides due to hereditary and internal limitations. The growth rate may follow a pattern similar to as shown in

Characteristic Growth Curves of Cultures of Microorganisms

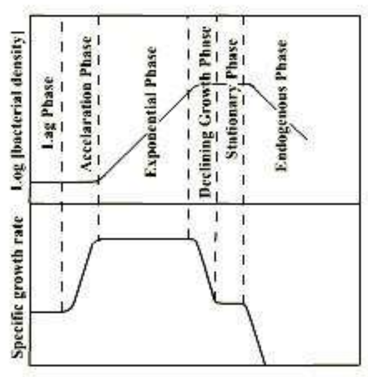


figure:

The curve shown may be divided into six well defined phases:

1. Lag Phase:adaptation to new environment, long generation time and null growth rate.
2. Accelaration phase: decreasing generation time and increasing growth rate.
3. Exponential phase: minimal and constant generation time, maximal and constant specific growth rate and maximum rate of substrate conversion.
4. Declining growth phase: increasing generation time and decreasing specific growth rate due to gradual decrease in substrate concentration and increased accumulation of toxic metabolites.
5. Stationary phase: exaustion of nutrients, high concentration of toxic metabolites, and cells in a state of suspended animation.
6. Endogenous phase: endogenous metabolism, high death rate and cell lysis.

Biomass Growth Rate

The most widely used expression for the growth rate of micro organisms is given by Monod:Total rate of microbial growth,

$$\frac{dx}{dt} = \frac{mmXS}{Ks + S}$$

where,
mm= maximum specific growth rate
X = micro organism concentration
S = substrate concentration
Ks= substrate concentration at one half the maximum growth rate

Similarly, rate of substrate utilization,

$$\frac{dS}{dt} = \frac{k\,X\,S}{Ks + S}$$

where,
k = maximum specific substrate utilization rate

Maintenance as Endogenous Respiration

Net growth rate of micro organisms is computed by subtracting from the total growth rate, the rate of micro organisms endogenously decayed to satisfy maintenance energy requirement. Therefore,

$$\text{Net rate of microbial growth} = \frac{mmX\ S}{Ks + S} - kdX$$

where,
kd = endogenous decay coefficient

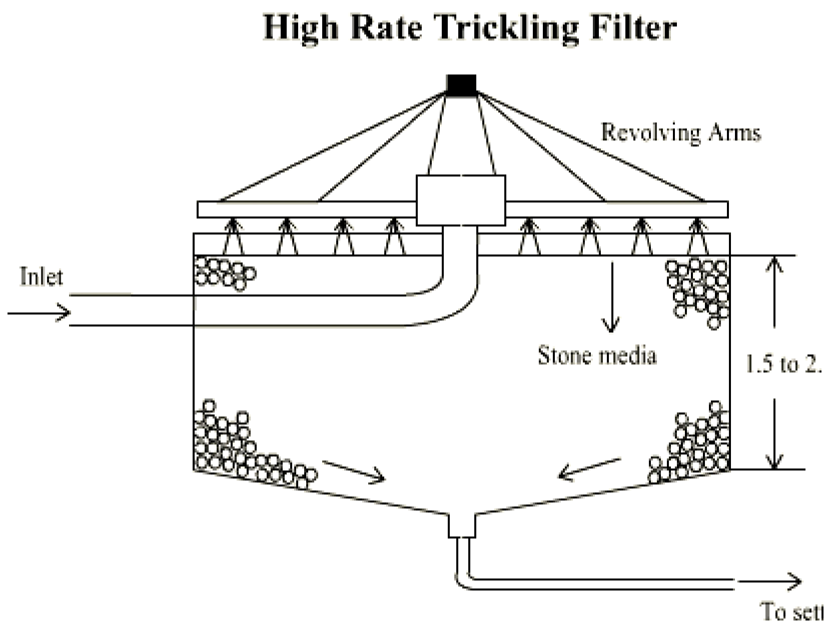
Growth Yield

Growth yield is defined as the incremental increase in biomass which results from the utilization of the incremental amount of substrate. The maximum specific growth rate is given by: mm =Y.k

where, Y is the maximum yield coefficient and is defined as the ratio of maximum mass of cells formed to the mass of substrate utilized. The coefficients Y, kd, k and Ks are designated as kinetic coefficients. The values of kinetic coefficients depend upon the nature of wastewater and operational and environmental conditions in biological reactor. The biological reactors can be completely mixed flow or plug flow reactor with or without recycle.

Trickling Filters

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



Process Description

- The wastewater in trickling filter is distributed over the top area of a vessel containing non-submerged packing material.
- Air circulation in the void space, by either natural draft or blowers, provides oxygen for the microorganisms growing as an attached biofilm.
- During operation, the organic material present in the wastewater is metabolised by the biomass attached to the medium. The biological slime grows in thickness as the organic matter abstracted from the flowing wastewater is synthesized into new cellular material.
- The thickness of the aerobic layer is limited by the depth of penetration of oxygen into the microbial layer.
- The micro-organisms near the medium face enter the endogenous phase as the substrate is metabolised before it can reach the micro-organisms near the medium face as a result of increased thickness of the slime layer and lose their ability to cling to the media surface. The liquid then washes the slime off the medium and a new slime layer starts to grow. This phenomenon of losing the slime layer is called ***sloughing***.
- The sloughed off film and treated wastewater are collected by an under drainage which also allows circulation of air through filter. The collected liquid is passed to a settling tank used for solid- liquid separation.

Types of Filters

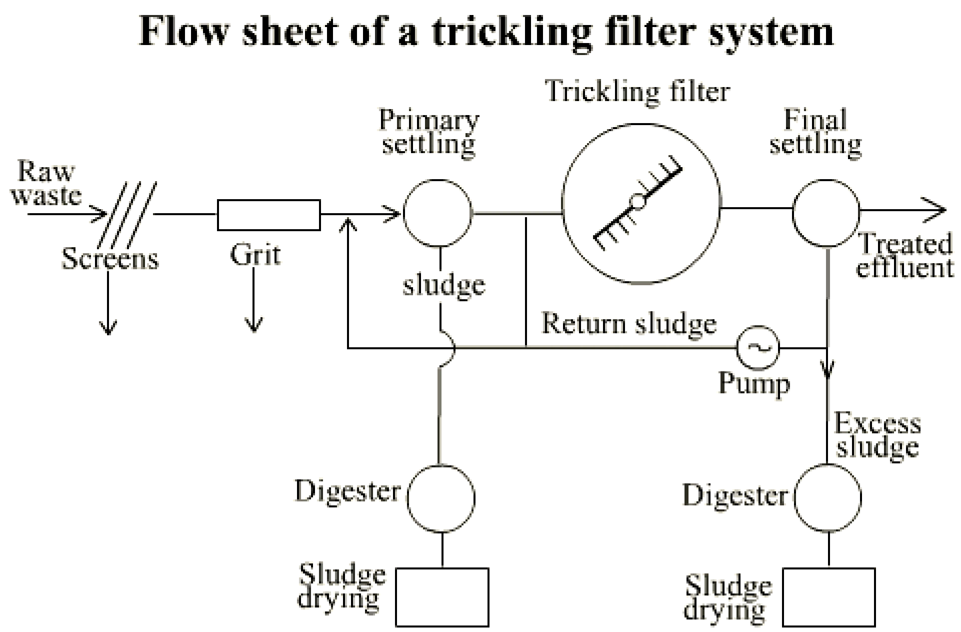
Trickling filters are classified as high rate or low rate, based on the organic and hydraulic loading applied to the unit.

S.No.	Design Feature	Low Rate	High Rate Filter

		Filter	
1.	Hydraulic loading, $m^3/m^2.d$	1 - 4	10 - 40
2.	Organic loading,kg BOD / m^3.d	0.08 - 0.32	0.32 - 1.0
3.	Depth, m.	1.8 - 3.0	0.9 - 2.5
4.	Recirculation ratio	0	0.5 - 3.0 (domestic wastewater) upto 8 for strong industrial wastewater.

- The hydraulic loading rate is the total flow including recirculation appied on unit area of the filter in a day, while the organic loading rate is the 5 day 20°C BOD, excluding the BOD of the recirculant, applied per unit volume in a day.
- Recirculation is generally not adopted in low rate filters.
- A well operated low rate trickling filter in combination with secondary settling tank may remove 75 to 90% BOD and produce highly nitrified effluent. It is suitable for treatment of low to medium strength domestic wastewaters.
- The high rate trickling filter, single stage or two stage are recommended for medium to relatively high strength domestic and industrial wastewater. The BOD removal efficiency is around 75 to 90% but the effluent is only partially nitrified.
- Single stage unit consists of a primary settling tank, filter, secondary settling tank and facilities for recirculation of the effluent. Two stage filters consist of two filters in series with a primary settling tank, an intermediate settling tank which may be omitted in certain cases and a final settling tank.

Process Design



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Generally trickling filter design is based on empirical relationships to find the required filter volume for a designed degree of wastewater treatment. Types of equations:

1. NRC equations (National Research Council of USA)
2. Rankins equation
3. Eckenfilder equation
4. Galler and Gotaas equation

NRC and Rankin's equations are commonly used. NRC equations give satisfactory values when there is no re-circulation, the seasonal variations in temperature are not large and fluctuations with high organic loading. Rankin's equation is used for high rate filters.

NRC equations**:** These equations are applicable to both low rate and high rate filters. The efficiency of single stage or first stage of two stage filters, E_2 is given by

$$E_2 = \frac{100}{1+0.44(F_{1.BOD}/V_1.Rf_1)^{1/2}}$$

For the second stage filter, the efficiency E_3 is given by

$$E_3 = \frac{100}{[(1+0.44)/(1- E_2)](F_{2.BOD}/V_2.Rf_2)^{1/2}}$$

where E_2= % efficiency in BOD removal of single stage or first stage of two-stage filter, E_3=% efficiency of second stage filter, $F_{1.BOD}$= BOD loading of settled raw sewage in single stage of the two-stage filter in kg/d, $F_{2.BOD} = F_{1.BOD}(1- E_2)$= BOD loading on second-stage filter in kg/d, V_1= volume of first stage filter, m^3; V_2= volume of second stage filter, m^3; Rf_1= Recirculation factor for first stage, R_1= Recirculation ratio for first stage filter, Rf_2= Recirculation factor for second stage, R_2= Recirculation ratio for second stage filter.

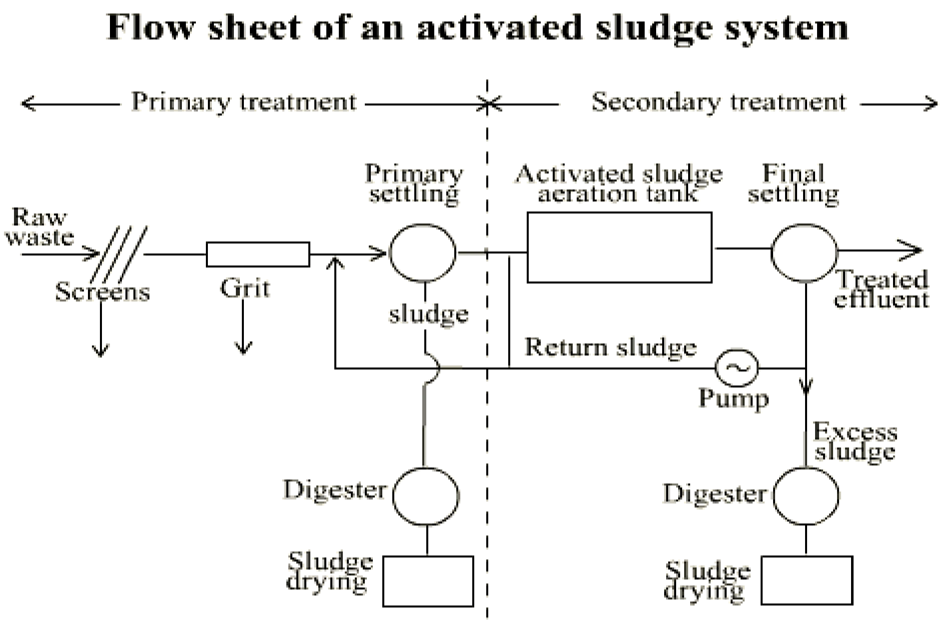
Rankins equation: This equation also known as Tentative Method of Ten States USA has been successfully used over wide range of temperature. It requires following conditions to be observed for single stage filters:

1. Raw settled domestic sewage BOD applied to filters should not exceed 1.2 kg BOD_5/day/ m^3 filter volume.
2. Hydraulic load (including recirculation) should not exceed 30 m^3/m^2 filter surface-day.
3. Recirculation ratio (R/Q) should be such that BOD entering filter (including recirculation) is not more than three times the BOD expected in effluent. This implies that as long as the above conditions are satisfied efficiency is only a function of recirculation and is given by:

$$E = \frac{(R/Q) + 1}{(R/Q) + 1.5}$$

Activated Sludge Process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process as shown in figure:



Activated sludge plant involves:

1. wastewater aeration in the presence of a microbial suspension,
2. solid-liquid separation following aeration,
3. discharge of clarified effluent,
4. wasting of excess biomass, and
5. return of remaining biomass to the aeration tank.

In activated sludge process wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter. Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy. In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge.

Activated Sludge Process Variables

The main variables of activated sludge process are the mixing regime, loading rate, and the flow scheme.

Mixing Regime

Generally two types of mixing regimes are of major interest in activated sludge process: ***plug***

flow and ***complete mixing***. In the first one, the regime is characterized by orderly flow of mixed liquor through the aeration tank with no element of mixed liquor overtaking or mixing with any other element. There may be lateral mixing of mixed liquor but there must be no mixing along the path of flow.

In complete mixing, the contents of aeration tank are well stirred and uniform throughout. Thus, at steady state, the effluent from the aeration tank has the same composition as the aeration tank contents.

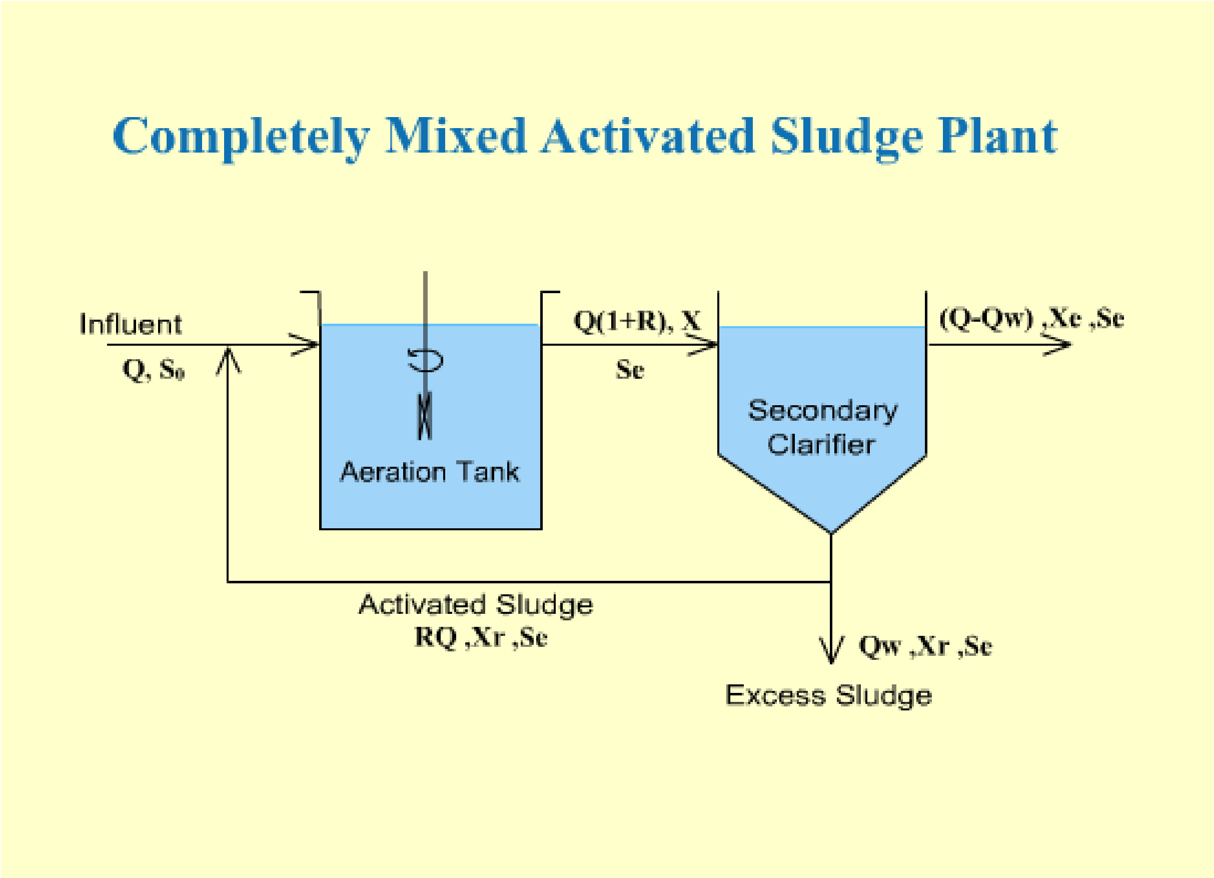
The type of mixing regime is very important as it affects (1) oxygen transfer requirements in the aeration tank, (2) susceptibility of biomass to shock loads, (3) local environmental conditions in the aeration tank, and (4) the kinetics governing the treatment process.

Loading Rate

A loading parameter that has been developed over the years is the ***hydraulic retention time*** (HRT), q, d

$$q = \frac{V}{Q}$$

V= volume of aeration tank, m^3, and Q= sewage inflow, m^3/d



Another empirical loading parameter is ***volumetric organic loading*** which is defined as the BOD applied per unit volume of aeration tank, per day.

A rational loading parameter which has found wider acceptance and is preferred is ***specific substrate utilization rate***, q, per day.

$$q = \frac{Q\,(S_O - S_e)}{V\ X}$$

A similar loading parameter is ***mean cell residence time*** or ***sludge retention time*** (SRT), q_c, d

$$q_c = \frac{V\,X}{Q_w X_r + (Q - Q_w X_e)}$$

where S_O and S_e are influent and effluent organic matter concentration respectively, measured as BOD_5 (g/m^3), X, X_e and $X_r$are MLSS concentration in aeration tank, effluent and return sludge respectively, and Q_w= waste activated sludge rate.

Under steady state operation the mass of waste activated sludge is given by

$$Q_w X_r = YQ\,(S_O - S_e) - k_d\,XV$$

where Y= maximum yield coefficient (microbial mass synthesized / mass of substrate utilized) and k_d = endogenous decay rate (d^{-1}) .

From the above equation it is seen that $1/q_c = Yq - k_d$

If the value of S_e is small as compared S_O, q may also be expressed as ***Food to Microorganism ratio***, F/M

$$F/M = Q(S_O - S_e) / XV = QS_O / XV$$

The q_c value adopted for design controls the effluent quality, and settleability and drainability of biomass, oxygen requirement and quantity of waste activated sludge.

Flow Scheme

The flow scheme involves:

- the pattern of sewage addition
- the pattern of sludge return to the aeration tank and
- the pattern of aeration.

Sewage addition may be at a single point at the inlet end or it may be at several points along the aeration tank. The sludge return may be directly from the settling tank to the aeration tank or through a sludge reaeration tank. Aeration may be at a uniform rate or it may be varied from the head of the aeration tank to its end.

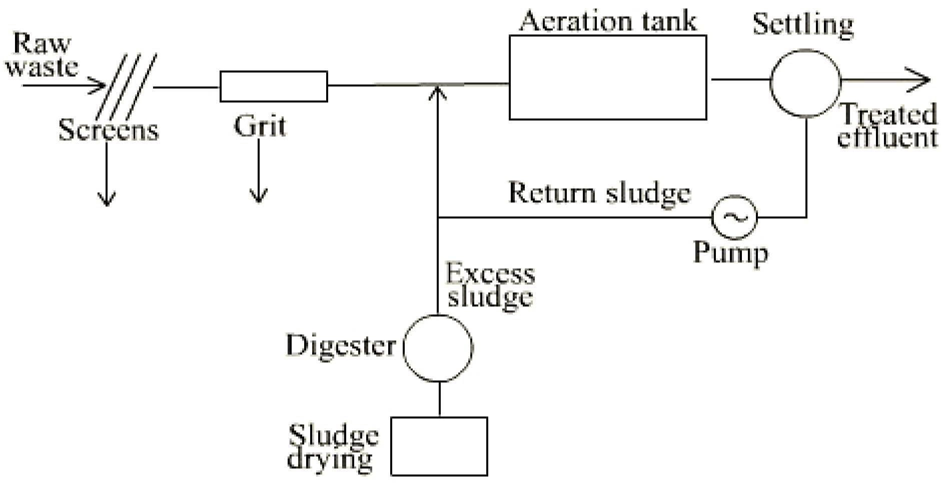
Conventional System and its Modifications

The conventional system maintains a plug flow hydraulic regime. Over the years, several modifications to the conventional system have been developed to meet specific treatment objectives. In ***step aeration*** settled sewage is introduced at several points along the tank length which produces more uniform oxygen demand throughout. ***Tapered aeration*** attempts to supply air to match oxygen demand along the length of the tank. ***Contact stabilization*** provides for reaeration of return activated sludge from from the final clarifier, which allows a smaller aeration or contact tank. ***Completely mixed*** process aims at instantaneous mixing of the influent waste and return sludge with the entire contents of the aeration tank. Extended aeration process operates at a low organic load producing lesser quantity of well stabilized sludge.

Extended Aeration Process

In **extended aeration** process the raw sewage goes straight to the aeration tank for traetment. The whole process is aerobic. This simplification implies longer aeration time which has earned for the process the name "extended aeration". The BOD removal efficiency of the extended aeration process is higher than activated sludge process which makes it especially desirable to use where it is to be followed by tertiary treatment for reuse.

Flow sheet of an extended aeration system



Design Consideration

The items for consideration in the design of activated sludge plant are aeration tank capacity and dimensions, aeration facilities, secondary sludge settling and recycle and excess sludge wasting.

Aeration Tank

The **volume of aeration tank** is calculated for the selected value of q_c by assuming a suitable value of MLSS concentration, X.

$$VX = \frac{YQq_c(S_O - S)}{1 + k_d q_c}$$

Alternately, the tank capacity may be designed from

$$F/M = QS_O / XV$$

Hence, the **first step** in designing is to choose a suitable value of $\mathbf{q_c}$ ***(or F/M***) which depends on the expected winter temperature of mixed liquor, the type of reactor, expected settling characteristics of the sludge and the nitrification required. The choice generally lies between 5 days in warmer climates to 10 days in temperate ones where nitrification is desired alongwith good BOD removal, and complete mixing systems are employed.

The **second step** is to select two interrelated parameters ***HRT, t and MLSS concentration***. It is seen that economy in reactor volume can be achieved by assuming a large value of X. However, it is seldom taken to be more than 5000 g/m^3. For typical domestic sewage, the MLSS value of 2000-3000 mg/l if conventional plug flow type aeration system is provided, or 3000-5000 mg/l for completely mixed types. Considerations which govern the upper limit are: initial and running cost of sludge recirculation system to maintain a high value of MLSS, limitations of oxygen transfer equipment to supply oxygen at required rate in small reactor volume, increased solids loading on secondary clarifier which may necessitate a larger surface area, design criteria for the tank and minimum HRT for the aeration tank.

The **length** of the tank depends upon the type of activated sludge plant. Except in the case of extended aeration plants and completely mixed plants, the aeration tanks are designed as long narrow channels. The **width** and **depth** of the aeration tank depends on the type of aeration equipment employed. The depth control the aeration efficiency and usually ranges from 3 to 4.5 m. The width controls the mixing and is usually kept between 5 to 10 m. **Width-depth ratio** should be adjusted to be between 1.2 to 2.2. The length should not be less than 30 or not ordinarily longer than 100 m.

Theory of Aeration

Aeration is a gas-liquid mass transfer process in which the driving force in the liquid phase is the concentration gradient (C_s - C) for slightly soluble gases.

Mass transfer per unit time $=K_L.a\ (C_s - C)$

where, K_L = Liquid film coefficient

$= \frac{\text{Diffusion coefficient of liquid (D)}}{\text{Thickness of film (Y)}}$

a = Interficial area per unit volume

C_s =saturation concentration at the gas-liquid interface and

C = some lower value in the body of the liquid.

The value of a increases as finer and finer droplets are formed, thus increasing the gas transfer. However, in practice, it is not possible to measure this area and hence the overall coefficient (K_L.a) per unit time, is determined by experimentation.

Adjustment for Field Conditions

The oxygen transfer capacity under field conditions can be calculated from the standard oxygen transfer capacity by the formula:

$$N = [N_s(C_s - C_L) \times 1.024^{T-20} a\ ]/9.2$$

where,

N = oxygen transferred under field conditions, kg O_2/h.

N_s= oxygen transfer capacity under standard conditions, kg O_2/h.

C_s= DO saturation value for sewage at operating temperature.

C_L= operating DO level in aeration tank usually 1 to 2 mg/L.

T = Temperature, degree C.

a = Correction factor for oxygen transfer for sewage, usually 0.8 to 0.85.

Aeration Facilities

- Oxygen may be supplied either by surface aerators or diffused aerators employing fine or coarse diffusers.
- The aeration devices apart from supplying the required oxygen shall also provide adequate mixing in order that the entire MLSS present in the aeration tank will be available for biological activity.
- Aerators are rated based on the amount of oxygen they can transfer to tap water under standard conditions of 20°C, 760 mm Hg barometric pressure and zero DO.

Aeration Facilities

The aeration facilities of the activated sludge plant are designed to provide the calculated oxygen demand of the wastewater against a specific level of dissolved oxygen in the wastewater.

Secondary Settling

Secondary settling tanks, which receive the biologically treated flow undergo zone or compression settling. ***Zone settling*** occurs beyond a certain concentration when the particles are close enough together that interparticulate forces may hold the particles fixed relative to one another so that the whole mass tends to settle as a single layer or "blanket" of sludge. The rate at which a sludge blanket settles can be determined by timing its position in a settling column test whose results can be plotted as shown in figure.

Compression settling may occur at the bottom of a tank if particles are in such a concentration as to be in physical contact with one another. The weight of particles is partly supported by the lower layers of particles, leading to progressively greater compression with depth and thickening of sludge. From the settling column test, the limiting solids flux required to reach any desired underflow concentration can be estimated, from which the rquired tank area can be computed.

The solids load on the clarifier is estimated in terms of (Q+R)X, while the overflow rate or surface loading is estimated in terms of flow Q only (not Q+R) since the quantity R is withdrawn from the bottom and does not contribute to the overflow from the tank. The secondary settling tank is particularly sensitive to fluctuations in flow rate and on this account it is recommended that the units be designed not only for average overflow rate but also for peak overflow rates. Beyond an MLSS concentration of 2000 mg/l the clarifier design is often controlled by the solids loading rate rather than the overflow rate. Recommended design values for treating domestic sewage in final clarifiers and mechanical thickeners (which also fall in this category of compression settling) are given in an earlier table.

Sludge Recycle

The MLSS concentration in the aeration tank is controlled by the sludge recirculation rate and the sludge settleability and thickening in the secondary sedimentation tank.

$$\frac{Q_r}{Q} = \frac{X}{X_r - X}$$

where Q_r = Sludge recirculation rate, m^3/d

The sludge settleability is determined by sludge volume index (SVI) defined as volume occupied in mL by one gram of solids in the mixed liquor after settling for 30 min. If it is assumed that sedimentation of suspended solids in the laboratory is similar to that in sedimentation tank, then $X_r = 10^6/SVI$. Values of SVI between 100 and 150 ml/g indicate good settling of suspended solids. The X_r value may not be taken more than 10,000 g/m^3unless separate thickeners are provided to concentrate the settled solids or secondary sedimentation tank is designed to yield a higher value.

Excess Sludge Wasting

The sludge in the aeration tank has to be wasted to maintain a steady level of MLSS in the system. The excess sludge quantity will increase with increasing F/M and decrease with increasing temperature. Excess sludge may be wasted either from the sludge return line or directly from the aeration tank as mixed liquor. The latter is preferred as the sludge concentration is fairly steady in that case. The excess sludge generated under steady state operation may be estimated by

$$q_c = \frac{VX}{Q_w X_r}$$

or $Q_w X_r = YQ (S_O - S) - k_d XV$

Design of Completely Mixed Activated Sludge System

Design a completely mixed activated sludge system to serve 60000 people that will give a final effluent that is nitrified and has 5-day BOD not exceeding 25 mg/l. The following design data is available.

Sewage flow = 150 l/person-day = 9000 m^3/day
BOD_5 = 54 g/person-day = 360 mg/l ; $BOD_u = 1.47\ BOD_5$
Total kjeldahl nitrogen (TKN) = 8 g/person-day = 53 mg/l
Phosphorus = 2 g/person-day = 13.3 mg/l
Winter temperature in aeration tank = 18°C
Yield coefficient Y = 0.6 ; Decay constant K_d = 0.07 per day ; Specific substrate utilization rate = $(0.038\ mg/l)^{-1}\ (h)^{-1}$ at 18°C
Assume 30% raw BOD_5 is removed in primary sedimentation, and BOD_5 going to aeration is, therefore, 252 mg/l (0.7 x 360 mg/l).

Design:
(a) *Selection of q_c, t and MLSS concentration*:

Considering the operating temperature and the desire to have nitrification and good sludge settling characteristics, adopt q_c = 5d. As there is no special fear of toxic inflows, the HRT, t may be kept between 3-4 h, and MLSS = 4000 mg/l.

(b) *Effluent BOD_5*:

Substrate concentration, $S = \frac{1}{qY}(1/q_c + k_d) = \frac{1}{(0.038)(0.6)}(1/5 + 0.07)$

S = 12 mg/l.

Assume suspended solids (SS) in effluent = 20 mg/l and VSS/SS =0.8.
If degradable fraction of volatile suspended solids (VSS) =0.7 (check later), BOD_5 of VSS in effluent = 0.7(0.8x20) = 11mg/l.

Thus, total effluent BOD_5 = 12 + 11 = 23 mg/l (acceptable).

(c) *Aeration Tank:*

$$VX = \frac{YQq_c(S_O - S)}{1 + k_d q_c} \quad \text{where } X = 0.8(4000) = 3200 \text{ mg/l}$$

$$\text{or } 3200\,V = \frac{(0.6)(5)(9000)(252-12)}{[1 + (0.07)(5)]}$$

$$V = 1500 \text{ m}^3$$

$$\text{Detention time, } t = \frac{1500 \times 24}{9000} = 4\text{h}$$

$$F/M = \frac{(252-12)(9000)}{(3200)(1500)} = 0.45 \text{ kg } BOD_5 \text{ per kg MLSS per day}$$

Let the aeration tank be in the form of four square shaped compartments operated in two parallel rows, each with two cells measuring 11m x 11m x 3.1m

(d) *Return Sludge Pumping:*

If suspended solids concentration of return flow is 1% = 10,000 mg/l

$$R = \frac{MLSS}{(10000)-MLSS} = 0.67$$

Q_r = 0.67 x 9000 = 6000 m^3/d

(e) *Surplus Sludge Production:*

$$\text{Net VSS produced } Q_w X_r = \frac{VX}{q_c} = \frac{(3200)(1500)}{(5)}(10^3/10^6) = 960 \text{ kg/d}$$

or SS produced =960/0.8 = 1200 kg/d

If SS are removed as underflow with solids concentration 1% and assuming specific gravity of sludge as 1.0,

Liquid sludge to be removed = 1200 x 100/1 = 120,000 kg/d
= 120 m^3/d

(f) *Oxygen Requirement:*

1. For carbonaceous demand,
   oxygen required = (BOD_u removed) - (BOD_u of solids leaving)
   = 1.47 (2160 kg/d) - 1.42 (960 kg/d)
   = 72.5 kg/h

2. For nitrification,
   oxygen required = 4.33 (TKN oxidized, kg/d)
   Incoming TKN at 8.0 g/ person-day = 480 kg/day. Assume 30% is removed in primary sedimentation and the balance 336 kg/day is oxidized to nitrates. Thus, oxygen required
   = 4.33 x 336 = 1455 kg/day = 60.6 kg/h
3. Total oxygen required
   = 72.5 + 60.6 = 133 kg/h = 1.0 kg/kg of BOD_u removed.

Oxygen uptake rate per unit tank volume = 133/1500
= 90.6 mg/h/l tank volume

(g) *Power Requirement*:

Assume oxygenation capacity of aerators at field conditions is only 70% of the capacity at standard conditions and mechanical aerators are capable of giving 2 kg oyxgen per kWh at standard conditions.

Power required = $\frac{136}{0.7 \times 2}$ = 97 kW (130 hp)

= (97 x 24 x 365) / 60,000 = 14.2 kWh/year/person

For worked out problems, refer to http://nptel.ac.in/courses

UNIT -VI

Disposing off Treated Sewage and Sludge

Objective: To learn the treatment and disposal methods of waste.

Syllabus:

Sources-types-composition-properties of solid waste- collection and handling separation and processing-land filling-incineration-composting, 5R concept (refuse, reduce, reuse, recover, recycle). **Hazardous waste management:** Definition and types- disposal and control methods of bio-medical waste-chemical, nuclear and e-wastes.

Introduction:

(i) **Screening**

(ii) A screen is a device with openings for removing bigger suspended or floating matter in sewage which would otherwise damage equipment or interfere with satisfactory operation of treatment units.

(iii) Types of Screens

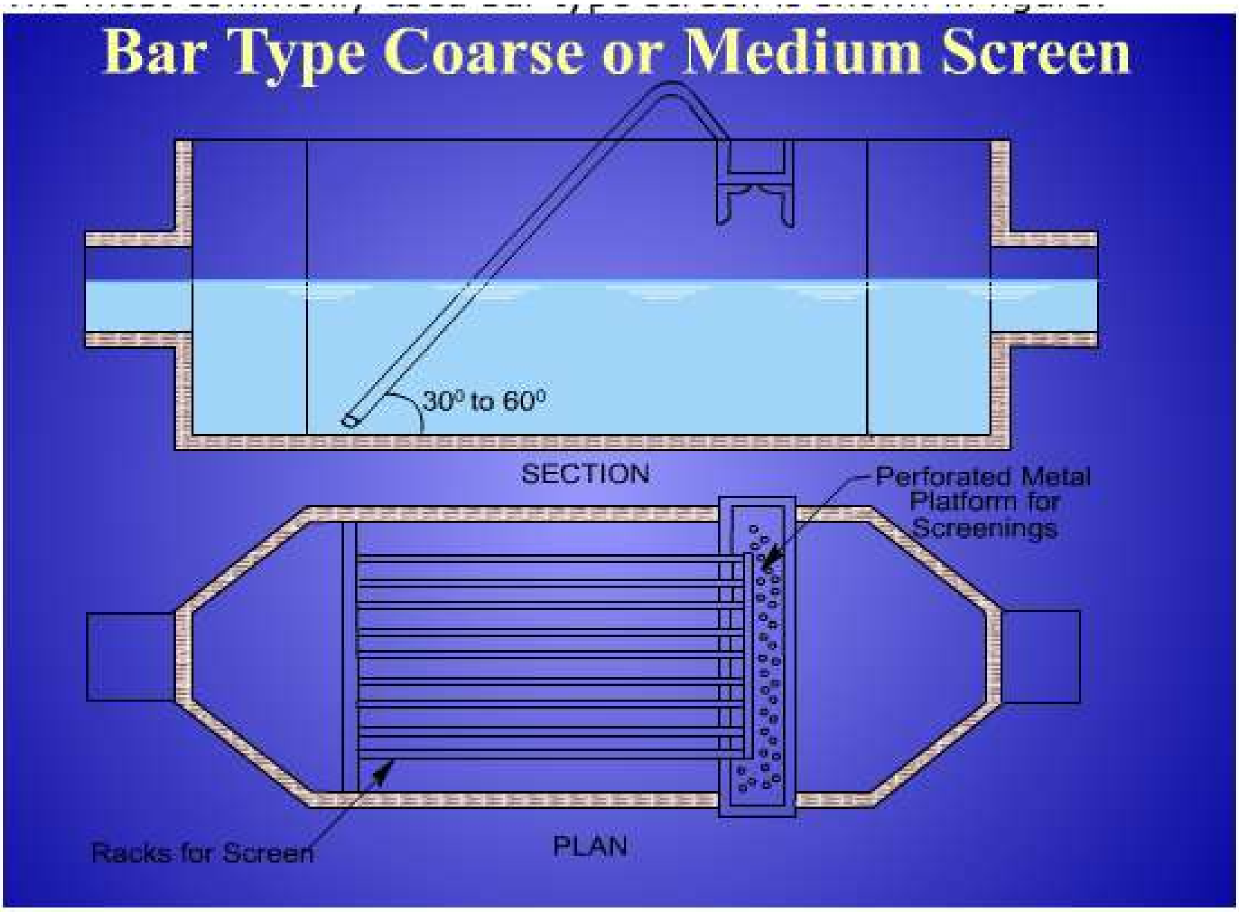
(iv) **Coarse Screens:** Coarse screens also called racks, are usually bar screens, composed of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows. Bar screens with relatively large openings of 75 to 150 mm are provided ahead of pumps, while those ahead of sedimentation tanks have smaller openings of 50 mm.

Bar screens are usually hand cleaned and sometimes provided with mechanical

(v) devices. These cleaning devices are rakes which periodically sweep the entire screen removing the solids for further processing or disposal. Hand cleaned racks are set usually at an angle of 45° to the horizontal to increase the effective cleaning surface and also facilitate the raking operations. Mechanical cleaned racks are generally erected almost vertically. Such bar screens have openings 25% in excess of the cross section of the sewage channel.

(vi) **Medium Screens:** Medium screens have clear openings of 20 to 50 mm. Bars are usually 10 mm thick on the upstream side and taper slightly to the downstream side. The bars used for screens are rectangular in cross section usually about 10 x 50 mm, placed with larger dimension parallel to the flow.

(vii) **Fine Screens:** Fine screens are mechanically cleaned devices using perforated plates, woven wire cloth or very closely spaced bars with clear openings of less than 20 mm. Fine screens are not normally suitable for sewage because of clogging possibilities.



The most commonly used bar type

screen is shown in figure

A photograph of a bar screen is given hereafter.

Velocity

The velocity of flow ahead of and through the screen varies and affects its operation. The lower the velocity through the screen, the greater is the amount of screenings that would be removed from sewage. However, the lower the velocity, the greater would be the amount of solids deposited in the channel. Hence, the design velocity should be such as to permit 100% removal of material of certain size without undue depositions. Velocities of 0.6 to 1.2 mps through the open area for the peak flows have been used satisfactorily. Further, the velocity at low flows in the approach channel should not be less than 0.3 mps to avoid deposition of solids.

(i) Head loss
(ii) Head loss varies with the quantity and nature of screenings allowed to accumulate between cleanings. The head loss created by a clean screen may be calculated by considering the flow and the effective areas of screen openings, the latter being the sum of the vertical projections of the openings. The head loss through clean flat bar screens is calculated from the following formula:

(iii) $h = 0.0729 (V^2 - v^2)$

(iv) where, h = head loss in m

(v) V = velocity through the screen in mps

(vi) v = velocity before the screen in mps

(vii) Another formula often used to determine the head loss through a bar rack is Kirschmer's equation:

(viii) $h = b\ (W/b)^{4/3}\ h_v \sin q$

(ix) where h = head loss,m

(x) b = bar shape factor (2.42 for sharp edge rectangular bar, 1.83 for rectangular bar with semicircle upstream, 1.79 for circular bar and 1.67 for rectangular bar with both u/s and d/s face as semicircular).

(xi) W = maximum width of bar u/s of flow, m

(xii) b = minimum clear spacing between bars, m

(xiii) h_v = velocity head of flow approaching rack, m = $v^2/2g$

(xiv) q = angle of inclination of rack with horizontal

(xv) The head loss through fine screen is given by

(xvi) h = (1/2g) (Q/CA)

(xvii) where, h = head loss, m
Q = discharge, m^3/s
C = coefficient of discharge (typical value 0.6)
A = effective submerged open area, m^2

(xviii) The quantity of screenings depends on the nature of the wastewater and the screen openings.

(xix) **Equalisation Tanks**

(xx) The equalization tanks are provided (i) to balance fluctuating flows or concentrations, (ii) to assist self neutralization, or (iii) to even out the effect of a periodic "slug" discharge from a batch process.

(xxi) s like ignitability, corrosivity, reactivity and toxicity. Note that in some cases, the active agents may be liquid or gaseous hazardous wastes. These are, nevertheless, classified as solid wastes as they are confined in solid containers. Typical examples of hazardous wastes are empty containers of solvents, paints and pesticides, which are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous wastes may cause explosions in incinerators and fires at landfill sites. Others such as pathological wastes from hospitals and radioactive wastes also require special handling. Effective management practices should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them harmless.

(xxii) Plastic waste: plastic are ubiquitous materials and finds in all parts our life and economy. They are light weight, low cost and command unique and versatile properties. They find use in agriculture, aviation, railways, telecommunication, building constructions, electronics, automotive, thermal insulation, household, furniture, toys and others.

(xxiii) Bio-Medical Waste

Bio-medical waste means any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities. Pertaining there to or in the production or testing of biological and including human anatomical waste (Body parts, body organs, Blood bags and blood preserves) animal waste, microbiology and bio-technology waste, waste sharps, discarded medicines and cytotoxic drugs, soiled waste, solid waste, incineration ash and chemical waste.

Properties of solid waste:

1. **Physical Characteristics**

Density

Knowledge of the density of a waste i.e. its mass per unit volume (kg/m^3) is essential for the design of all elements of the solid waste management system viz. Community storage, transportation and disposal. For example, in high-income countries, considerable benefit is derived through the use of compaction vehicles on collection routes, because the waste is typically of low density. The situation in low-income countries is quite different: a high initial density of waste precludes the achievement of high compaction ratio. Consequently, compaction vehicles offer little or no advantage and are not cost-effective.

Significant changes in density occur spontaneously as the waste moves from source to disposal, as a result of scavenging, handling, wetting and drying by the weather, vibration in the collection vehicles. Density is as critical in the design of a sanitary landfill as it is for the storage, collection and transportation of waste. Efficient operation of a land fill requires compaction of the waste to optimum density after it is placed.

Density of Municipal Solid Wastes in Some Cities

Sl. No	City	Density (Kg/m^3)
1.	Bengaluru	390
2.	Vadodara	457
3.	Delhi	422

4.	Hyderabad	369
5.	Jaipur	537
6.	Jabalpur	395
7.	Raipur	405

Bulk Density Measurement

Materials and apparatus:

- Wooden box of l m3 capacity
- Wooden box of 0.028 m3 capacity
- Spring balance weighing up to 50 kg.

Procedure: The solid waste should be taken in the smaller 0.028 m3 box to give a composite sample, from different parts of the heap of waste, and then weighed with the help of a spring balance. After weighing, this smaller box (0.028 m3) is emptied in bigger l m3 box and the weight of the waste poured into the bigger box is noted. This is repeated till the larger box is filled to the top. The waste should not be compacted by pressure. Fill the l m3 box three times and take the average. Thus the weight per cubic meter is obtained.

Moisture Content:

Moisture content of solid wastes is usually expressed as the weight of moisture per unit weight of wet material.

A typical range of moisture contents is 20 – 45% representing the extremes of wastes in an arid climate and in the wet season of a region having large precipitation. Values greater than 45% are however not uncommon. Moisture increases the weight of solid waste and therefore the cost of collection and transport. Consequently, waste should be insulated (protect) from rainfall or other extraneous water. Moisture content is a critical determinant in the economic feasibility.

Moisture content is a critical determinant in the economic feasibility of waste treatment and processing methods by incineration since energy (e.g. heat) must be supplied for evaporation of water and in raising the temperature of the water vapour.

Size of Waste Constituents:

The size distribution of waste constituents in the waste stream is important because of its significance in the design of mechanical separators and shredder and waste treatment process. This varies widely and while designing a system, proper analysis of the waste characteristics should be carried out.

Calorific Value:

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of 25^oc from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water, the combustion water remains in the liquid state. However, during combustion the temperature of the combustion gases remains above 100^Oc so that the water resulting from combustion is in the vapour state.

While evaluating incineration as a means of disposal or energy recovery, the following points should be kept in view:
Organic material yields energy only when dry;
The moisture contained as free water in the waste reduces the dry organic material per kilogram of waste and requires a significant amount of energy for evaporation; and
The ash content of the waste reduces the proportion of dry organic material per kilogram of waste. It also retains some heat when removed from the furnace.

2. **Chemical Characteristics**

   Knowledge of chemical characteristics of waste is essential in determining the efficacy of any treatment process. Chemical characteristics include (i) chemical; (ii) bio-chemical; and (iii) toxic.

Chemical: Chemical characteristics include pH, Nitrogen, Phosphorus and Potassium

(N-P-K), total Carbon, C/N ratio, and calorific value.

Bio-Chemical: Bio-Chemical characteristics include carbohydrates, proteins, natural fibre, and biodegradable factor.

Toxic: Toxicity characteristics include heavy metals, pesticides, insecticides, Toxicity test for Leachates (TCLP), etc.

Chemical composition of Municipal Solid Wastes in Indian Cities

Population Range(in millions)	Number of cities surveyed	Moisture%	Organic Matter %	Nitrogen as total. N%	Phosphorous as P_2O5 %	Potassium as K_2O%	C/N ratio	Calorific value in Kcal/kg
0.1-0.5	12	25.81	37.09	0.71	0.63	0.83	30.94	1009.89
0.5-1.0	15	19.52	25.14	0.66	0.56	0.69	21.13	900.61
1.0-2.0	9	26.98	26.89	0.64	0.82	0.72	23.68	980.05
2-5	3	21.03	25.60	0.56	0.69	0.78	22.45	907.18
>5	4	38.72	39.07	0.56	0.52	0.52	30.11	800.70

Collection: The functional element of collection includes not only the gathering of solid wastes and recyclable materials, but also the transport of these materials, after collection, to the location where the collection vehicle is emptied. This location may be materials processing facility, a transfer station, or a landfill disposal site.

COLLECTION COMPONENTS:

waste collection does not mean merely the gathering of wastes, and the process includes, as well, the transporting of wastes to transfer stations and/or disposal sites. To elaborate, the factors that influence the waste collection system include the following.

i) Collection points: These affect such collection system components as crew size and storage, which ultimately control the cost of collection. Note that the collection points depend on locality and may be residential, commercial or industrial.

(ii)Collection frequency: Climatic conditions and requirements of a locality as well as containers and costs determine the collection frequency. In hot and humid climates, for example, solid wastes must be collected at least twice a week, as the decomposing solid wastes produce bad odour and leachate.

And, as residential wastes usually contain food wastes and other putrescible (rotting) material, frequent collection is desirable for health and aesthetic reasons. Besides climates, the quality of solid waste containers on site also determines the collection frequency. For instance, while sealed or closed containers allow collection frequency up to three days, open and unsealed containers may require daily collection. Collection efficiency largely depends on the demography of the area (such as income groups, community, etc.), where collection takes place.

While deciding collection frequency, therefore, you must consider the following:

- cost, e.g., optimal collection frequency reduces the cost as it involves fewer trucks, employees and reduction in total route distance;
- storage space, e.g., less frequent collection may require more storage space in the locality;
- Sanitation, e.g., frequent collection reduces concerns about health, safety and nuisanceassociated with stored refuse.

(i) Storage containers:

Proper container selection can save collection energy, increase the speed of collection and reduce crew size.Most importantly, containers should be functional for the amount and type of materials and collection vehicles used. Containers should also be durable, easy to handle, and economical, as well as resistant to corrosion, weather and animals. In residential areas, where refuseis collected manually, standardised metal or plastic containers are typically required for waste storage. When mechanised collection systems are used, containers are specifically designed to fit the truck-mounted loading mechanisms.

While evaluating residential waste containers, consider the following:

- Efficiency, i.e., the containers should help maximise the overall collection efficiency.
- Convenience, i.e., the containers must be easily manageable both for Residents and collection crew.
- Compatibility ,i.e., the containers must be compatible with collection equipment.
- Public health and safety, i.e., the containers should be securely covered and Stored.
- Ownership, i.e., the municipal ownership must guarantee compatibility with collection equipment.

(ii) Collection crew :

The optimum crew size for a community depends on labour and equipment costs, collection methods and route characteristics. The size of the collection crew also depends on the size and type of collection vehicle used, space between the houses, waste generation rate and collection frequency. For example, increase in waste generation rate and quantity of wastes collected per stop due to less frequent collection result in a bigger crew size. Note also that the collection vehicle could be a motorised vehicle, a pushcart or a trailer towed by a suitable prime mover (tractor, etc.). It is possible to adjust the ratio of collectors to collection vehicles such that the crew idle time is minimised. However, it is not easy to implement this measure, as it may result in an overlap in the crew collection and truck idle time. An effective collection crew size and proper workforce management can influence the productivity of the collection system. The crew size, in essence, canhave a great effect on overall collection costs. However, with increase in collection costs, the trend in recent years is towards:

- decrease in the frequency of collection;
- increase in the dependence on residents to sort waste materials;
- Increase in the degree of automation used in collection.
- This trend has, in fact, contributed to smaller crews in municipalities

v)Collection route :

The collection programme must consider the route that is efficient for collection. An efficient routing of collection vehicles helps decrease costs by reducing the labour expended for collection. Proper planning of collection route also helps conserve energy and minimise working hours and vehicle fuel consumption. It is necessary therefore todevelop detailed route configurations and collection schedules for the selected collection system. The size of each route, however, depends on the amount of waste collected per stop, distance between stops, loading time and traffic conditions. Barriers, such as railroad, embankments, rivers and roads with heavy traffic, can be considered to divide route territories. Routing (network) analyses and planning can:

- increase the likelihood of all streets being serviced equally and consistently;
- help supervisors locate or track crews quickly;
- Provide optimal routes that can be tested against driver judgement and experience.

(vi)Transfer station:

A transfer station is an intermediate station between final disposal option and collection point in order to increase the efficiency of the system, as collection vehicles and crew remain closer to routes. If the disposal site is far from the collection area, it is justifiable to have a transfer station, where smaller collection vehicles transfer their loads to larger vehicles, which then haul the waste long distances. In some instances, the transfer station serves as a pre-processing point, where wastes are dewatered, scooped or compressed. A centralised sorting and recovery of recyclable materials are also carried out at transfer stations The unit cost of hauling solid wastes from a collection area to a transfer station and then to a disposal site decreases, as the size of the collection vehicle increases. This is due to various reasons such as the following:

- labour costs remain constant;
- the ratio of payload to vehicle load increases with vehicle size;

- the waiting time, unloading time, idle time at traffic lights and driver rest period are constant, regardless of the collection vehicle size.

PROCESSING

Purpose of processing of solid waste:

The processing of wastes helps in achieving the best possible benefit from every functional element of the solid waste management (SWM) system and, therefore, requires proper selection of techniques and equipment for every element. Accordingly, the wastes that are considered suitable for further use need to be paid special attention in terms of processing, in order that we could derive maximum economical value from them.

Processing techniques essentially, are

(i)Improving efficiency of SWM system:

Various processing techniques are available to improve the efficiency of SWM system. For example, before waste papers are reused, they are usually baled to reduce transporting and storage volume requirements. In some cases, wastes are baled to reduce the haul costs at disposal site, where solid wastes are compacted to use the available land effectively. If solid wastes are to be transported hydraulically and pneumatically, some form of shredding is also required.

Shredding is also used to improve the efficiency of the disposal site.

ii) Recovering material for reuse: Usually, materials having a market, when present in wastes in sufficient quantity to justify their separation are most amenable to recovery and recycling. Materials that can be recovered from solid wastes include paper, cardboard, plastic, glass, ferrous metal, aluminium and other residual metals.

(iii)Recovering conversion products and energy:

Combustible organic materials can be converted to intermediate products and ultimately to usable energy. This can be done either through incineration, pyrolysis, composting or bio-digestion. Initially, the combustible organic matter is separated from the other solid waste components. Once separated, further processing like shredding and drying is necessary before the waste material can be used for power generation.

Important processing techniques used routinely in municipal solid waste systems include:

1. **Mechanical volume/size reduction**
2. **Thermal volume reduction (incineration)**
3. **Manual separation of waste components**

1. Mechanical volume and size reduction is an important factor in the development and operation of any SWM system. The main purpose is to reduce the volume (amount) and size of waste, as compared to its original form, and produce waste of uniform size.We will discuss the processes involved in volume and size reduction along with their selection criteria, equipment requirement and design consideration.

Volume reduction or compaction:

Volume reduction or compaction refers to densifying wastes in order to reduce their volume. Some of the benefits of compaction include:

- reduction in the quantity of materials to be handled at the disposal site
- improved efficiency of collection and disposal of wastes
- increased life of landfills
- Economically viable waste management system.

However, note the following disadvantages associated with compaction:

- poor quality of recyclable materials sorted out of compaction vehicle
- difficulty in segregation or sorting (since the various recyclable materials are mixed and compressed in lumps)
- Bio-degradable materials (e.g., leftover food, fruits and vegetables) destroy the value of paper and plastic material.

Size reduction or shredding:

This is required to convert large sized wastes (as they are collected) into smaller pieces. Size reduction helps in obtaining the final product in a reasonably uniform and considerably reduced size in comparison to the original form. But note that size reduction does not necessarily imply volume reduction, and this must be factored into the design and operation of SWM systems as well as in the recovery of materials for reuse and conversion to energy.

- In the overall process of waste treatment and disposal, size reduction is implemented ahead of:
- Land filling to provide a more homogeneous product. This may require less cover material and less frequent covering than that without shredding.
- This can be of economic importance, where cover material is scarce or needs to be brought to the landfill site from some distance.
- Recovering materials from the waste stream for recycling.
- Baling the wastes –a process sometimes used ahead of long distance transport of solid wastes –to achieve a greater density. making the waste a better fuel for incineration waste energy recovery facilities. (The size reduction techniques, coupled with separation techniques such as screening, result in a more homogeneous mixture of relatively uniform size, moisture content and heating value, and thereby improving the steps of incineration and energy recovery.
- Reducing moisture, i.e., drying and dewatering of wastes.
-

2 .Thermal volume reduction: the volume of municipal wastes can be reduced by more than 90% by incineration. In the past, incineration was quite common. However, with more restrictive air pollution control requirements necessitating the use of expensive claenup equipment only a limited number of municipal incinerators are currently in operation. More recently, increased haul distances to available landfill sites and increased fuel costs have brought about a renewed interest in incineration and a number of new incinerator projects are now on the drawing boards.

3. Manual component separation: the manual separation of solid waste components can be accomplished at the source where solid wastes are generated, at a transfer station, at a centralized processing station, or at the disposal site. Manual sorting at the source of generation is the most positive way to achieve the recovery and reuse of materials. The number and types of components salvaged or sorted (e.g., cardboard and high quality paper, metals and wood) depend on the location, the opportunities for recycling and resale market.

SEPERATION:

Waste sorting is the process by which waste is separated into different elements. Waste sorting can occur manually at the household and collected through curbside collection schemes, or automatically separated in materials recovery facilities or mechanical biological treatment systems. Hand sorting was the first method used in the history of waste sorting.

Waste segregation means dividing waste into dry and wet. **Dry waste** includes wood and related products, metals and glass. **Wet waste**, typically refers to organic waste usually generated by eating establishments and are heavy in weight due to dampness. Waste can also be segregated on basis of biodegradable or non-biodegradable waste.

Segregation of Waste:

Waste Can be segregated as:

1. **Bio Degradable Waste:** Bio Degradable waste includes organic waste, e.g. kitchen waste, Vegetables, fruits, flowers, leaves from the garden and paper.
2. **Non Bio Degradable Waste**:-Non Biodegradables can be further segregated into:

- Recyclable Waste : Plastics, Paper, Glass, Metal Etc.
- Toxic Waste:-Old Medicine, paints, Chemicals, bulbs, Spray Cans, fertilizer and pesticide containers, batteries, shoe polish.
- Soiled: - Hospital waste such as cloth soiled with blood and other body fluids. Toxic &soiled waste must be disposed of with utmost care.

Method of Segregation of Solid Waste:

Segregation or sorting can be carried out manually or through semi- mechanised and fully mechanized systems.

Manual sorting operation:

Manual sorting operation comprises of,

1. Unloading the waste

2. Manually (with protective measures) spreading the waste

3. Hand picking (with protective measures) visually identifiable waste for reuse

4. Collecting and stockpiling the remaining waste

Semi-mechanized sorting operation:

Semi-mechanized sorting operations consists of,

1.Unloading of waste (mechanized)

2. Loading of waste on conveyor belts (mechanized)

3. Hand picking of visually identifiable waste off the belt for reuse (manual)

4. Collecting, stocking and reloading the remaining waste (mechanized)

Fully-mechanized sorting operation:

Fully-mechanized sorting operations comprise of,

1. Unloading of waste

2. Size reduction of waste through shredders and crushers

3. Size separation of waste using screening devices

4. Density separation of waste

5. Magnetic separation of waste

6. Compaction of waste through balers/crushers

7. Reloading of waste.

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Land filling:

A sanitary landfill is a low-lying area that is filled with waste rejects. It has a liner at the bottom to prevent the groundwater from contaminating with the mix of the liquid that oozes from the waste that is buried called the leachate. Waste is buried in-between layers of soil and is compacted nicely to make it a hard surface. When the landfill is completed, it is capped with a layer of clay or a synthetic liner in order to prevent water from entering. A final topsoil cover is placed, compacted and graded, and various forms of vegetation may be planted in order to reclaim the otherwise useless land.

Ideal for biodegradable wastes from kitchens, hotels etc. At household level, a vessel or tray more than 45 cm deep, and 1 x 0.60m may be sufficient A hole shall be provided at one end in the bottom for draining the leachate out into a tray or vessel Lay 1” thick layer of baby metal or gravel at the bottom of the tray Above that lay an old gunny bag or a piece of thick cloth, a layer of coconut husk upside down over it and above that a 2” thick layer of dry leaves and dry cow dung (powdered)Lay the biodegradable waste over it. Introduce good quality earthworms into it (~ 10 g for 0.6 x 0.45 x 0.45 m box). If the waste is dry, sprinkle water over it daily Rainwater should not fall into the tray or vessel or box Keep it closed. If the box is kept under bright sun earthworms will go down and compost can be taken from the top Compost can be dried and stored Continue putting waste into the box Add little cow dung at intervals. Do not use vermin wash directly. Dilute in the ratio 1:10 before use.

Biomedical wastes: The principal sources of hazardous biological wastes are hospitals and biological research facilities. The ability to infect other living organisms and the ability to produce toxins are the most significant characteristics of hazardous biological wastes. This group mainly includes malignant tissues discarded during surgical procedures and contaminated materials, such as hypodermic needles, bandages and outdated drugs. This waste can also be generated as a by-product of industrial biological conversion processes.

Chemical wastes: Most hazardous chemical wastes can be classified into four groups: synthetic organics, inorganic metals, salts, acids and bases, and flammables and explosives. Some of the chemicals are hazardous because they are highly toxic to most life forms. When such hazardous compounds are present in a waste stream at levels equal to, or greater than, their threshold levels, the entire waste stream is identified as hazardous.

Nuclear waste: Substances that emit ionising radiation are radioactive. Such substances are hazardous because prolonged exposure to radiation often results in damage to living organisms. Radioactive substances are of special concern because they persist for a long period. The period in which radiation occurs is commonly measured and expressed as half-life, i.e., the time required for the radioactivity of a given amount of the substance to decay to half its initial value. For example, uranium compounds have half-lives that range from 72 years for U232 to 23,420,000 years for U236. The management of radioactive wastes is highly controlled by national and state regulatory agencies. Disposal sites that are used for the long-term storage of radioactive wastes are not used for the disposal of any other solid waste.

e-waste: Disposal of e-wastes is a particular problem faced in many regions across the globe. Computer wastes that are landfilled produces contaminated leachates which eventually pollute the groundwater. Acids and sludge obtained from melting computer chips, if disposed on the ground causes acidification of soil. It is estimated that 75% of electronic items are stored due to uncertainty of how to manage it. These electronic junks lie unattended in houses, offices, warehouses etc. and normally mixed with household wastes, which are finally disposed off at landfills. This necessitates implementable management measures.

In industries management of e-waste should begin at the point of generation. This can be done by waste minimization techniques and by sustainable product design. Waste minimization in industries involves adopting:

1) inventory management,
2) production-process modification,
3) volume reduction,
4) recovery and reuse.

Disposal:

Regardless of their form (i.e., solid, liquid, or gas), most hazardous waste is disposed off either near the surface or by deep burial. The table shows the various hazardous waste disposal methods: