STUDY NOTES

CE3303 WATER SUPPLY AND WASTEWATER ENGINEERING

COURSE OBJECTIVES:

To introduce students to various components and design of water supply scheme, water treatment methods, water storage distribution system, sewage treatment and disposal and deign of intake structures and sewerage system.

UNIT I WATER SUPPLY

Estimation of surface and subsurface water resources - Predicting demand for water- Impurities of water and their significance - Physical, chemical and bacteriological analysis - Waterborne diseases - Standards for potable water. Intake of water: Pumping and gravity schemes.

UNIT II WATER TREATMENT

Objectives - Unit operations and processes - Principles, functions, and design of water treatment plant units, aerators of flash mixers, Coagulation and flocculation – Clarifloccuator - Plate and tube settlers - Pulsator clarifier - sand filters - Disinfection - softening, removal of iron and manganese -Defluoridation - Softening - Desalination process - Residue Management - Construction, Operation and Maintenance aspects

UNIT III WATER STORAGE AND DISTRIBUTION

Storage and balancing reservoirs - types, location and capacity. Distribution system: layout,

hydraulics of pipe lines, pipe fittings, valves including check and pressure reducing valves, meters,analysis of distribution systems, leak detection, maintenance of distribution systems, pumpingstations and their operations - House service connections.

UNIT IV PLANNING AND DESIGN OF SEWERAGE SYSTEM

Characteristics and composition of sewage - Population equivalent - Sanitary sewage flow estimation- Sewer materials - Hydraulics of flow in sanitary sewers - Sewer design - Storm drainage-Stormrunoff estimation - Sewer appurtenances - Corrosion in sewers - Prevention and control – Sewagepumping-drainage in buildings - Plumbing systems for drainage

UNIT V SEWAGE TREATMENT AND DISPOSAL

Objectives - Selection of Treatment Methods - Principles, Functions, - Activated Sludge Process andExtended aeration systems - Trickling filters - Sequencing Batch Reactor(SBR) - UASB - WasteStabilization Ponds - Other treatment methods - Reclamation and Reuse of sewage - RecentAdvances in Sewage Treatment - Construction, Operation and Maintenance aspects. - Dischargestandards-sludge treatment -Disposal of sludge.

UNIT - I
WATER SUPPLY
OBJECTIVES OF A WATER SUPPLY SYSTEM

(i) To supply safe and wholesome water to consumers.

(ii) To supply water in adequate quantity.

(iii) To make water easily available to consumers, so as to encourage personal and household cleanliness.

(Wholesome means unpolluted water free from toxic substances, organic matter, minerals and pathogens).

Components of a water supply system

(i) Collection - Surface water and ground water sources. (Perennial rivers, dams, intake structures).

(ii) Transmission - Conveyance of water from the source to the treatment plants

(Pipelines/Conduits, canals, aqueducts, pumps etc.).

(iii) Purification - To remove physical, chemical and biological impurities from water and make it safe for consumption - Water Treatment plant (filter beds, softening units etc.).

(iv) Distribution - To distribute treated purified water to the consumers under pressure - (Elevated Reservoirs, pipelines, pumps etc.)

ESTIMATION OF SURFACE AND SUB-SURFACE WATER RESOURCES

1. Natural Ponds and Lakes

2. Streams and Rivers

3. Impounding Reservoirs

1. **Natural Ponds and Lakes as surface sources of supplies**

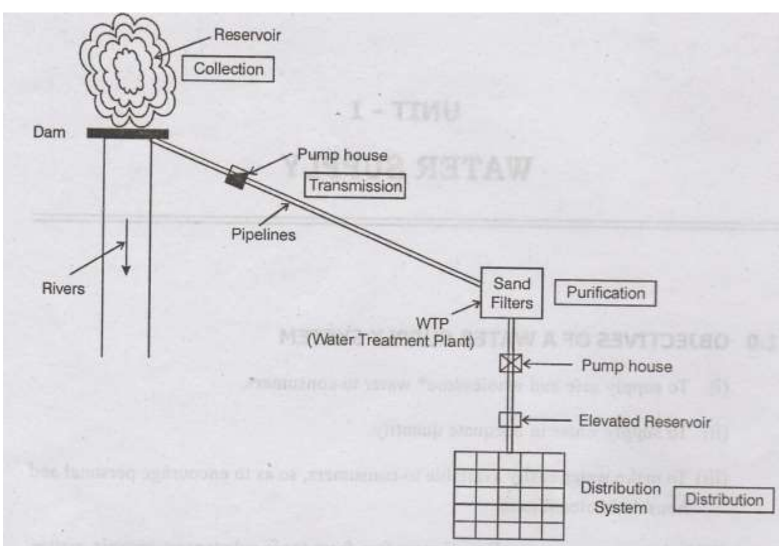


Fig. 1.1 Components of a water supply system

Natural large-sized depression formed on earth surface, when filled with water is called a pond or lake.

Surface runoff from nearby catchment area drains water into lakes

Sometimes, small springs also drain underground water into ponds and lakes.

Quality of water in Lakes:

• Good quality

• There is no need of much purification

• Self purification of water occurs in lakes due to:

* Sedimentation of suspended matter

* Bleaching of colour

* Removal of bacteria etc.

• Larger and older lakes are more purer.

• As lakes are still and standing waters, it contribute to growth of algae and aweeds, imparting bad smell, taste, colour to waters.

Quantity of water

• Small quantity of water

• The quantity depends on - Catchment area- Annual rainfall- Geological formation

• Lakes cannot be used as a principal source of water supply.

• Lakes are useful for small towns and hilly areas only.

• When no other sources are available, lakes may be used for water supply.

• Example - Water supply to Bombay city is from lakes.

2. Streams and Rivers as surface sources of supplies

(a) Streams

* As the quantity of water is less, it is not suitable for water supply schemes.

* They are useful for small villages and hilly areas.

* However, large perennial streams may be used as sources of water by providing storage reservoirs.

(b) River

* Most important source of water for public water supply.

* Rivers may be perennial or non-perennial.

* In perennial rivers, water is available throughout the year.

* Perennial rivers can be used as a source for water supply.

Quantity - Good source of water supply to cities mostly located nearby the rivers.

Quality - Water quality is not reliable.

* River water has large amount of silt, sand and suspended matter.

* The disposal of sewage into river contaminates the waters.

* Proper treatment is required for river waters before supply to public.

3. Storage reservoirs / Impounding reservoirs as surface sources of supplies

The rivers or streams when directly used for water supply schemes fail due to the following problems.

• During low flows (dry season), it cannot meet the demand of the consumers.

• During high flows, it leads to devastating floods. Hence, it is necessary to build a barrier or dam or storage / impounding reservoirs at the upstream of rivers to store the excess water (during high flows) and supply to public (during low flows).

An Impounding Reservoir is an artificial lake created by construction of dam across a water course.

The objective is to impound (store) water for water supply schemes.

Parts of an Impounding reservoir

(i) Dam to hold back water. (ii) Spillway to discharge excess flow

(iii) Gate valves to regulate water flow**Location of impounding reservoir is selected based on the following factors**

(i) Existence of suitable dam site - short and narrow dams.

(ii) Quantity of water available should be sufficient to meet the demand throughout the year.

(Rainfall, runoff, catchment area characteristics.)

(iii) Distance and elevation of reservoir with reference to point of distribution.

Longer distance - cost will be high

Higher elevation – cost is low due to gravity flow. Pumping is not required

(iv) Density and distribution of population over the catchment area. If the population is less, the pollution of streams will be less.

(v) Existence of towns, highways, railyards, cultivable areas.

(vi) Geological conditions of storage basin.

Existence of calcareous bed rocks may cause hardness to water.

Existence of fissures may lead to water loss by percolation.

Selection of dam site

The selection of a site for constructing dam is governed by following factors:

(i) Suitable foundation.

(ii) Length of dam should be small with maximum storage volume. The river valley should be narrow with large upstream basin for reservoir.

(iii) Bed level of dam site should be higher than river basin.

(iv) Construction materials should be locally available.

(v) Reservoir basin shuld be water tight

(vi) Land value should be low

(vii) Accessible and well connected by roads, rails to towns and cities.(viii) Labour easily available.

Storage capacity of reservoir

It is determined from the Contour maps of the area (Topographic survey)

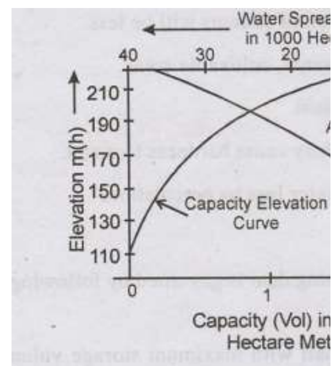


Fig. 1.3 The Area-Ele

$$\text{Volume} = h\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \ldots\ldots A_{n-1}\right] \qquad \textit{Trapezoidal formula}$$

(or)

$$= [(A_1 + A_n) + 4(A_2 + A_4 + \ldots\ldots) + 2(A_3 + A_5 + \ldots\ldots)] \qquad \textit{Prismoidal formula}$$

The volume of water that can be stored by the reservoir at a certain water surface elevation can be computed by summing up the increment between two elevations.

$$\underbrace{\Delta s}_{\text{Increment of storage}} = \underbrace{\Delta a}_{\text{average area of two elevations}} \times \underbrace{\Delta h}_{\text{elevation difference}}$$

In the absence of topographic maps, capacity can be determined using, formulae.

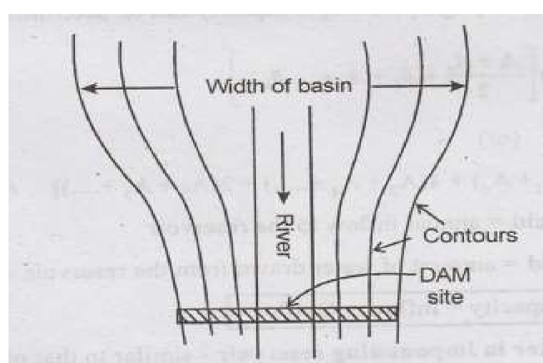


Fig. 1.2 Contour map of a suitable site for a dam

Catchment yield = annual inflow to the reservoir

Reservoir yield = amount of water drawn from the reservoir

Storage capacity = Inflow = Outflow

Quality of water in impounding reservoir - similar to that of natural lakes

Quantity of water in impounding reservoir.

GROUND WATER AS A SOURCE OF WATER SUPPLY

The part of rainfall that percolates through soil pores, contributes to ground water and appears as springs, wells and infiltration galleries.

Characteristics of water table

a. It follows the profile of ground surface.

b. It is not static, fluctuates, rises during wet season and falls in dry season.

c. Where the water table level and ground level meets, springs or streams may appear.

1. **Springs**

Springs are outcrops of ground water at foot of hills and river banks. The different types of springs are:

a) Gravity springs

b) Artesian springs

c) Surface springs

(a) Gravity springs

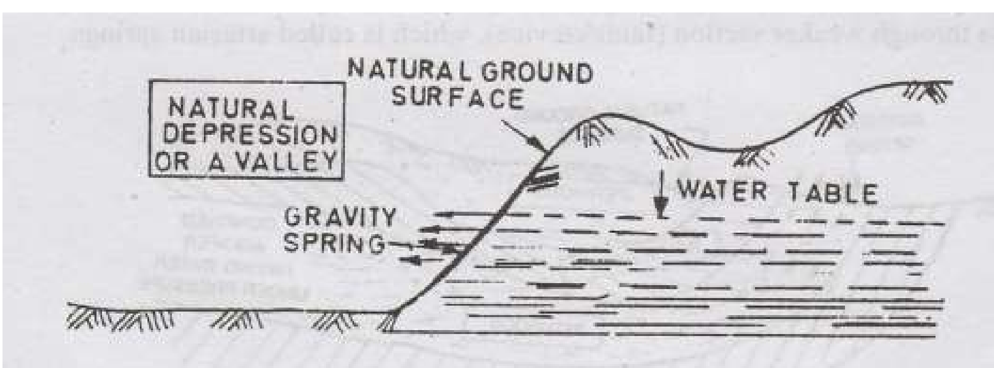


Fig. 1.4 Gravity spring

When the ground water table rises high and water overflows through sides of natural valley, a gravity spring is formed. The flow fluctuates with the rise (or) fall of water table.

b) Surface springs

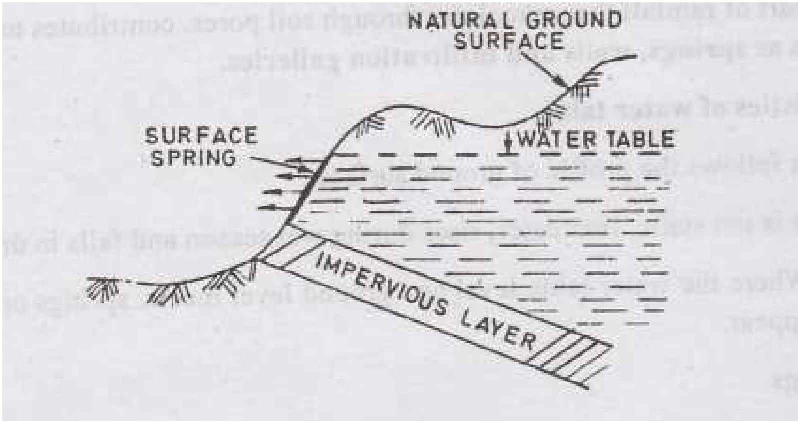


Fig. 1.5 Surface spring

Surface springs are formed when an impervious stratum supporting underground storage becomes inclined causing the water table to rise up and get exposed to the ground surface.

The quantity of water in these springs is uncertain.

c) Artesian springs

When the water bearing strata between two impervious strata is under pressure, the water flows through weaker section (fault/crevice), which is called artesian springs.

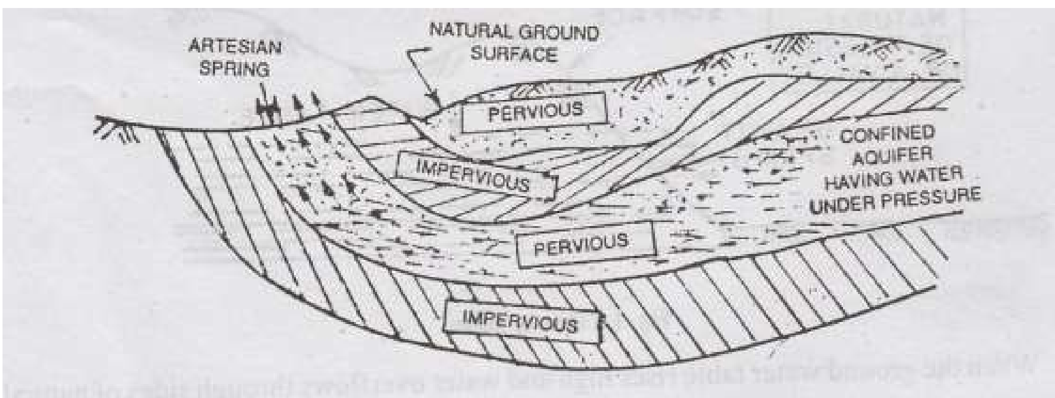


Fig. 1.6 Artesian spring

2. **Wells**

Well are vertical cylindrical openings from surface to a water bearing: formation

Classification

a) Based on the type of Aquifer tapped

(i) Shallow wells

• Tapping of uppermost water bearing strata

Drawbacks:

• Large fluctuations in yield soon tab-img

• Quality of water is poor

(ii) Deep wells

• Tapping of deeper and larger aquifers

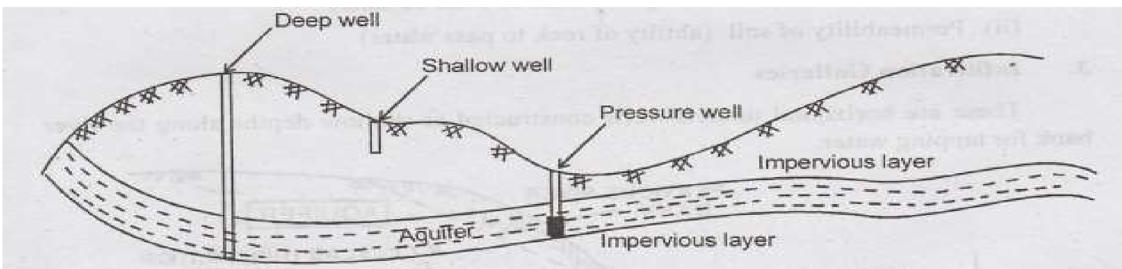
b) Based on the Condition of flow

(i) Gravity well

Water flows under gravity into the well under atmospheric pressure.

(ii) Pressure well

Aquifer is confined between two impervious strata. Water flows under pressure greater than atmospheric pressure.



c. Type of construction

(i) Dug well or percolation well (open wells)

(ii) Sunk wells

(iii) Driven well

(iv)Tube well

(i) Dug wells

- Shallow wells with masonry walls. The well sinks under masonry weight

- More masonry is added and excavation proceeds till the required height.

- Cheap and easy construction

- Useful for Villages and small Towns

- Quality - water is easily contaminated

- Quantity - Larger diameter increases the yield.ut

(ii) Tube wells

Constructed by drilling auger boring into ground using machinery

Types: Deep and shallow wells.

Methods of drilling

(a) Percussion drilling

(b) Core drilling.

(c) Rotary drilling

Storage capacity of ground water

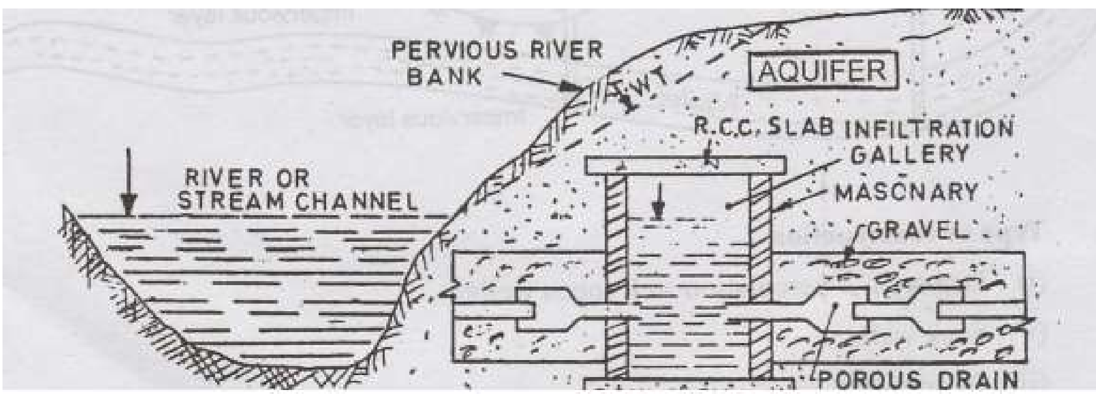
Storage capacity depends on

(i) Porosity of soil (Percentage of voids to total volume)

(ii) Permeability of soil (ability of rock to pass water)

3. Infiltration Galleries

These are horizontal tunnels/wells constructed at shallow depths along the river bank for tapping water.



An infiltration gallery is constructed of mansonry walls with roof slab and extracts water from aquifers by various porous lateral drain pipes. The pipes are covered with gravel to prevent entry of sand and particles. The galleries are laid at slope and water collected in them is taken to a sump well, from where it is pumped.

The discharge from infiltration gallery is computed by

$$Q = KL\left(\frac{H^2 - h^2}{2R}\right)$$

K - permeability coefficient of aquifer

L-length of gallery

R- radius of influence

H-static water level

h - depth on pumping equilibrium.

PREDICTING DEMAND FOR WATER

The various types of water demand which a city may have is classified as:

1. Domestic water demand (Residential)

2. Industrial water demand

3. Institutional and Commercial water demand

4. Demand for public uses

5. Fire demand

6. Water required to compensate losses in wastes and thefts

1. Domestic water demand

• The water required in residential buildings for drinking, cooking, bathing, gardening, flushing etc.

• The domestic water demand is 50 to 60% of the total water consumption.

• The demand may vary according to the living conditions of consumers (LIG/ MIG/HIG).

• LIG-Low income group

Table 1.1: Minimum domestic water consumption for Indian cities

Description	Amount of water in lpcd
Bathing	55
Washing clothes	20
Flushing of W.C	30
Washing house	10
Cooking	5
Drinking	5
Total	135

2. Industrial water demand

• Represents the water demand of industries (existing and anticipated in future)

• The demand varies according to the number and type of industries in the city.

• The average per capita consumption for industrial needs is 50 lpcd.

• In Industrial cities, the per capita water requirement is 450 lpcd.

• Water demand of certain industries is given below:

a. Automobile - 40 kilo litre per vehicle produced

b. Leather - 40 kilo litre per tonne produced

c. Textile - 80 to 140 litre per tonne produced

3. Institutional and Commercial water demand

Water requirement of Institutions such as Hotels, Hospitals, Schools, Colleges, Offices, Railway Stations, Factories etc.

The water demand depends on the nature of city and number of commercial establishments.

On an average, the per capita demand is 20 lpcd.

Table 1.2: Water for Institutional needs

Institution	Water requirement (lpcd)
Offices	45 to 90
Schools	45 to 90
Hotels	135 to 180
Hostels	180
Hospitals	450
Railway station	70

4. Demand for public or civic use

The quantity of water required for public utility purposes such as watering of public parks, gardening, washing and sprinkling on roads, public fountains etc.

It accounts to 5% of the total water consumption

On an average, it is 10 lpcd

5. Fire demand

In thickly populated and industrial areas, fire outbreaks may cause serious damages. The quantity of water required for fire fighting is called fire demand and it is stored in Storage reservoirs. The minimum water pressure available in fire hydrants should be 100 to 150 kN/m2 (10 to 15 m of water head).

For cities having population > 50,000, water required for fire fighting in kilo litre.

$= 100\sqrt{P}$, where P = population in thousands.

Rate of Fire Demand

Empirical formulae are used to calculate fire demand.

(i) Kuichling's Formula

$Q=3182\sqrt{P}$ mano no

Q = Water required in litre/minute

P = Population in thousands

(ii) Freeman formula

Q-1136[P/10+10]

(iii) National Board of Fire Under Writers formula

(American Insurance Association)

(a) For a central congested high valued city

(i) Population ≤ 2,00,000

(ii) Population > 2,00,000

(b) For a residential city, the water required for fire fighting is as follows:

Small buildings - 2200 litre/minute

Larger buildings - 4500 litre/minute

High rise Apartments - 7650 to 13,500 litre/minute

(iv) Buston's formula

$$Q = 5663\sqrt{P}$$

$$Q = \frac{4360\,R^{0.275}}{(t+12)^{0.757}}$$

This formula takes into account probability of occurrence of fire.

$$Q = 4637\sqrt{P}\left[1 - 0.01\sqrt{P}\right]$$

t - duration of fire (minimum 30 min). R- period of occurrence of fire (minimum 1 year)

6. Water required to compensate losses (thefts/wastes)

(i) Leakage/overflow from service reservoirs

(ii) Leakage from main/ service pipe connections

(iii) Leakage/losses on consumer's premises (unmetered)

(iv) Leakage from public taps

(v) Defective pipe joints

(vi) Cracked pipes

(vii) Loose valves/ fittings

(viii) Unauthorised water connections

(ix) Damaged meter

PER CAPITA DEMAND

The per capita demand (q) in litres per day per head (annual average daily consumption per person)

= Total yearly water requirement of city in litres / 365×Design population

Factors affecting per capita demand

1. Size of City / Type of Community - The fluctuations in demand depends upon th size of city.

- Large city-fluctuations are less and demand is more
- Small city - demand is less
- Residential Community - more fluctuations in demand
- Industrial Community - Fluctuation is less

2. Standard of living/habits of people

- Higher the standard of living - demand for water is more

3. Climatic conditions

- Hot climate - Usage of water will increase (bathing, lawn sprinkling etc.)
- Cold climate - Water is wasted to prevent freezing of pipes

4. Quality of water

- Good quality water - usage
- Poor quality water - usage is less.

5. Pressure in the supply

- High pressure - increased usage.
- Low pressure - decreased usage.

6. System of supply - water supply may be continuous (24 hrs) or intermitter Intermittent supply reduces the demand.

7. Sewerage - Flushing system increases water demand.

8. Policy of metering - Use of water decreases when the supplies are metered.

9. Water rates - Increase in water rates reduces the consumption

10. Age of community - Older communities use less water. Developing new communiti require large quantity of water for construction works.

11. Lawn sprinkling - Enforcement of lawn sprinkling regulations can reduce pe demands.

VARIATIONS IN DEMAND

The per capita consumption of water varies seasonally, monthly, daily and hourly.

(i) Seasonal variations

Summer season - large use of water.

Winter season - lesser use of water.

Rainy season - much lesser use of water.

(ii) Daily variations

Sundays / Holidays - more usage of water.

Weekdays - less usage of water.

(iii) Hourly variations

Early morning (0 to 6 hours) - less consumption of water.

Between 8 to 11 am - Peak consumption of water.

Between 1 to 4 pm - Water consumption is less.

Between 7 to 9 pm - high or peak consumption of water

Late night hours - Minimum consumption of water

The hourly variations in water demand is shown in figure 1.8

Assessment of Variations in Demand

(i) Maximum daily consumption 180% of average daily demand 100 ylish mumix=1.8

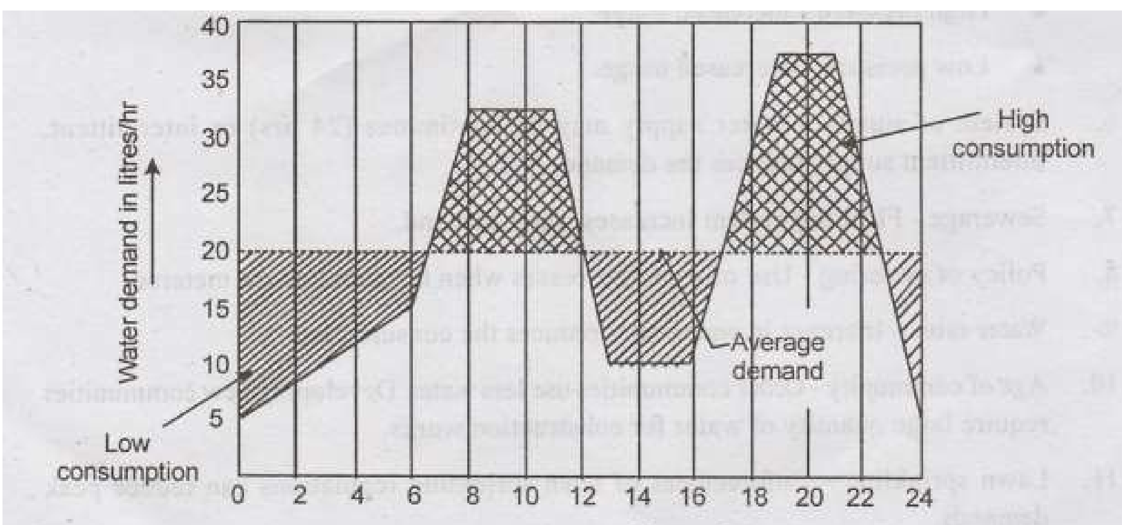
Where q = average daily demand

(ii) Maximum hourly consumption (peak demand) = 150% of its average hourly cosumption

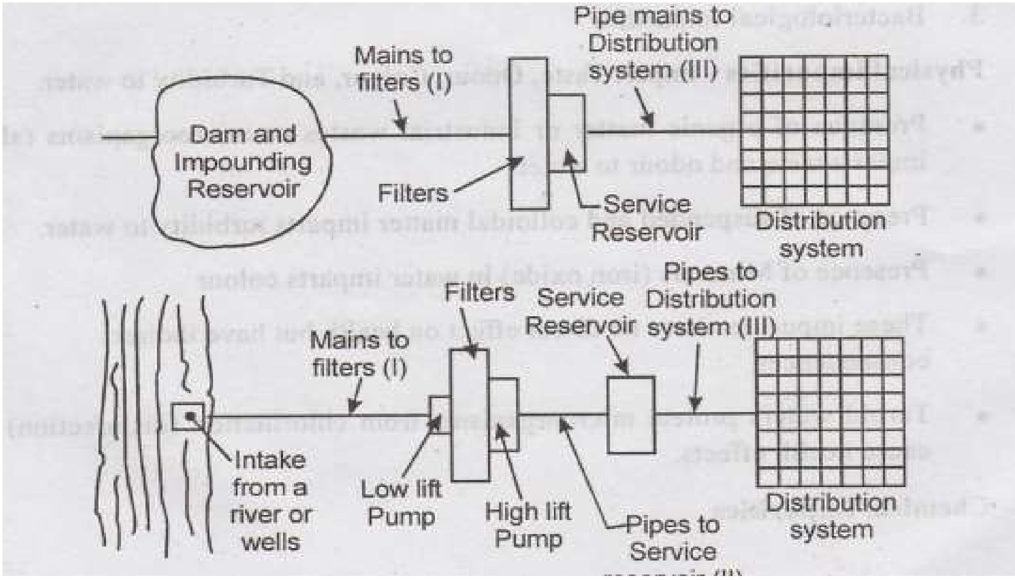
= 1.5 x Average hourly consumption of maximum day

(iii) Maximum hourly consumption of maximum day

1.5 x [Max. daily demand /24]



Effect of variations in demand on the design capacities of different components of a water supply scheme.



1. Source of supply - Designed for maximum daily consumption

2. Pipe Mains (Type I & II) - Designed for maximum daily consumption

3. Filter and other units of water treatment plant - Designed for maximum daily consumption or twice the average daily consumption (including reserve for repairs)

4. Pumps - Same as filter and WTP units

5. Distribution system (Type III) - Designed for maximum hourly demand of maximum day plus reserve for fire

6. Service reservoir - Designed for hourly fluctuations, fire demand, emergency reserve etc.

IMPURITIES OF WATER AND THEIR SIGNIFICANCE

Impurities in water can also be classified as

1. Physical impurities

2. Chemical impurities

3. Bacteriological impurities

1. Physical impurities - Impart Taste, Odour, Colour, and Turbidity to water.

• Presence of organic matter or industrial wastes or microorganisms (algae) imparts taste and odour to water.

• Presence of suspended and colloidal matter imparts turbidity to water.

• Presence of Minerals (iron oxide) in water imparts colour

• These impurities have no direct effect on health but have indirect consequences

• Turbid waters protect microorganisms from chlorination (disinfection) and cause health effects.

2. Chemical Impurities

PHYSICAL, CHEMICAL AND BACTERIOLOGICAL ANALYSIS

Bacteriological impurities

The presence of pathogens or disease causing microorganisms in water makes it dangerous for human consumption.

The coliform group of bacteria - Escherichia coli (E.Coli) is normally found in the intestinal tract of animals and human beings. E.Coli is not harmful, but its presence in water indicates the presence of other pathogenic micro organisms (like typhoid bacillus) in water.

CHARACTERISTICS OF WATER (WATER ANALYSIS)

1. Physical Characteristics

2. Chemical Characteristics nidolgomsem

3. Microbiological Characteristics

1. Physical Characteristics

(i) Colour

(ii) Taste and odour

(iii) Temperature

(iv) Turbidity

(i) Colour

• Colour in water is not harmful from health point of view but it may cause staining/discolouration of clothes and is also objectionable from aesthetic point of view.

• Presence of dissolved organic matter, inorganic materials, algae, aquatic microbes impart colour to water.

• Colour is detected by naked eye or measured against hazen or platinic chloride or cobalt scale (standard colour scale) using tintometer.

Table 1.3: Chemical impurities

Impurities	Causes	Effects
A. Inorganic/ Mineral		
a) Suspended	Silt + clay	Turbidity
b) Dissolved	Ca + Mg (Carbonate + bicarbonate)	Hardness and Alkalinity
	Ca + Mg (Sulphate + Chloride)	Hardness and Corrosion of boilers
	Sodium (Na) (Carbonate+bicarbonate)	Alkalinity and softness
	Nitrates	> 45 mg/l cause Methaemoglobinemia "Blue babies"
	Chlorides of Na	Brackish taste
	Fluorides of Na	>1.5 mg/l cause teeth staining
	Iron oxide	Taste, color, hardness
	Manganese	Taste and brown colour
B. Organic		
(i) Suspended		
(a) Vegetable	Decayed leaves, algae, fungi	Acidity, taste, colour change, water suspicious
b) Animal	Dead animals, hair, insects	Bacteria, water becomes contaminated, dangerous for health
(ii) Dissolved a) Vegetable	large quantity of Albuminoid Nitrogen + free ammonia + chlorides	Bacteria water suspicious
b) Animal	large quantity of	Disease producing

• The tintometer has an eye piece with two holes, one for standard colour and other for

• For public water supplies, the colour of water on cobalt scale should be less then 20.

Significance of colour

Colour of water indicates the type of impurity present in water. Eg: of water indicates the presence of manganese. (Isitatond) Inoigol

(ii) Taste and Odour

• Taste and odour is due to the presence of mineral salts, industrial domestic sewage, organic matter and microorganisms.

• It is difficult to measure taste and odour.

• It is measured in terms of Threshold Odour Number which is the "volume of sample (in cm3) required to be added to 100 cc of odour free fresh water, where the mixture just starts giving smell in diluted sample.

Example: If 6 cc of water is added to 100 cc fresh water - no odour is produced, while 7 cc of water added to 100 cc fresh water gives odour. Then the threshold no. is 6.

• For public water supplies, the threshold no. > 3

• Alternatively, an Osmoscope (i.e. inhaling through 2 tubes) is used. Diluted water samples are prepared. One tube is placed in diluted water sample. The 20 lbs other tube is placed in original water sample. The mixture that gives the first detectable odour is taken as threshold odour.

Odour intensity (PO value) - The number of dilutions of fresh water is known as PO value or odour intensity.

PO value / Meaning

0 - No perceptible odour

1 - Very faint odour

2 - Faint odour, detectable

3 - Distinct odour, readily detectable

4 - Very distinct odour

5 - Strong / Intense odour

6 Extremely strong odour

(iii) Temperature

The preferable temperature is 10° to 20°C

Temperature higher than 25°C is objectionable.

Significance

Dissolution of gases (dissolved oxygen) depends on temperature.

BOD and biological (bacterial) activities in water are temperature dependant.

(iv)Turbidity (Optical property)

It is the resistance of water to passage of light. It is caused due to suspended and I colloidal solids in water.

The permissible turbidity for domestic water - 5 to 10 ppm

Methods of measuring turbidity of water:

(a) Turbidity rod

(b) Jackson's turbidimeter

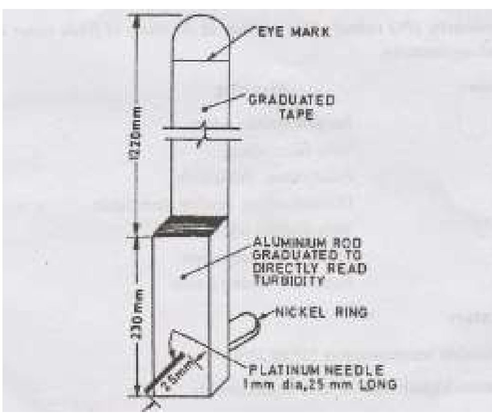
(c) Baylis turbidimeter

(d) Nephelometers

(a) Turbidity rod

It is a graduated aluminium rod attached to platinum needle and nickel ring at bottom, graduated tape at top with position of eye marked.

The Rod is inserted in turbid water. Reading is taken when the needle just disappears. Turbidity is expressed in ppm.



(b) Jackson's Turbidimeter

• Used when turbidity > 100 ppm

• It consists of a metal stand holding a metal container and graduated glass tube.

• A candle is placed below the standenado ai

• The image of flame is seen through turbid water in glass tube

• The water level is increased till the flame just disappear

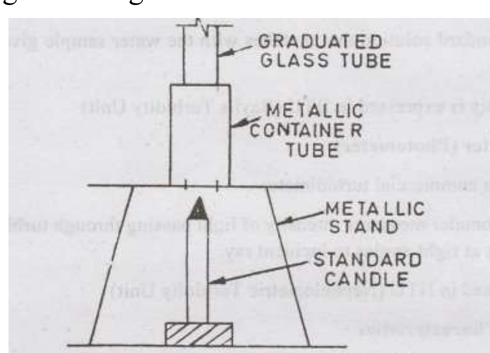


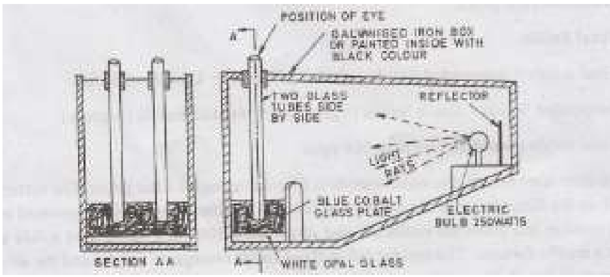
Fig 1.11 Section through a jackson candle turbidimeter

• The height of water column is the Turbidity of water.

Expressed in JTU (Jackson Turbidity Unit)

(c) Baylis Turbidimeter

Very accurate instrument used when Turbidity < 5 units



• It consists of galvanised iron box with two glass tubes on one end and 250 watt bulb with reflector on other end. The tubes are surrounded by blue cobalt glass.

• In one tube, standard solution and other tube, water sample are placed.

• The standard solution is changed till it matches with the turbid water sample.

• The standard solution that matches with the water sample gives the turbidity value.

• Turbidity is expressed in BTU (Baylis Turbidity Unit)

(d) Nephelometer (Photometer)

• Modern commercial turbidimeter

• A photometer measures intensity of light passing through turbid water after it scatters at right angles to incident ray.

• Expressed in NTU (Nephelometric Turbidity Unit)

2. Chemical Characteristics

(i) Total solids

(ii) Chlorides

(iii) Hardness

(iv) pH value

(v) Metals and other chemicals

(vi) Nitrogen and its compounds

(vii) Dissolved gases

(i) Total Solids

Total solids = Suspended Solids + Colloidal Solids + Dissolved Solids

Suspended Solids = Fixed Solids (Inorganic) + Volatile Solids (organic)

Total solids should be less than 500 ppm

To determine Solids, the water sample is filtered through a filter paper. The material retained on the filter paper is the suspended solids. The filtered water is evaporated and the day residue left gives the colloidal and dissolved solids. The suspended solids are burnt in a muffle furnace. The residue left is fixed solids (inorganic solids) and the solids that vaporizes is Volatile solids (organic matter)

Significance

High solids content indicates contamination and presence of excessive minerals.

Suspended solids cause turbidity and imparts colour.

Dissolved solids imparts colour, taste and makes it salty.

(ii) Chlorides

• Presence of sodium chloride (Nacl) in water.

• Source of chloride in water are from sewage effluents, mineral deposits and ingression of salt water.

• Chloride is determined by titration with standard silver nitrate using potassium chromate as indicator.

• The permissible level of chloride is 200 mg/l

Significance

Presence of chloride in water indicates sewage contamination

(iii) Hardness

presence of salts such as carbonates, bicarbonates, chlorides, sulphates of Calcium and Magnesium.

Total Hardness = Temporary (Carbonate) Harduess + Permanant (Non Carbonate)

Hardness

Temporary hardness (Carbonate hardness)

• It is due to the presence of carbonates and bicarbonates of calcium and Magnesium.

• It can be easily removed by boiling or adding lime.

Permanent hardness (Non carbonate hardness)

• This is due to the presence of sulphates, chlorides and nitrates of Calcium and Magnesium.

• Special water softening methods are required to remove permanent hardness.

• Hardness is expressed in degree

Degree of hardness	Nature of water
1	Extremely soft water
2	Very soft water
3	Soft water
$\boxed{6}$	Reasonably soft water
$\boxed{7}$	Reasonably hard water
9	Hard water
11	Very hard water
15	Excessive hard water
17	Too hard to use

For Potable water, hardness should be within the range of 5 to 8.

Methods to determine Hardness:

(a) Clark's Method

Hardness is found by determining the standard soap solution required to obtain permanent lather with water sample of known volume at constant shaking.

(b) Hehner's Method

Temporary Hardness - Determined by Titration with std soln. H,SO, using methyl orange as indicator.

Permanent Hardness - Standard Sodium Carbonate is added to water sample and evaporated. The amount of Sodium Carbonate required in excess to convert sulphate/ chloride into Carbonate gives the permanent hardness.

(c) Versenate Method

Hardness is found by titration against Di-Ethylene diamine tetracitic acid (EDTA) solution using Erichrome BlackT as indicator.

Excessive hardness is objectionable because

• Soap required is more

• Scaling in boilers and heating systems from.gninoffo

• Corrosion of pipes and plumbing fixtures

(iv) pH (Hydrogen ion concentration)

Gives the degree of acidity or alkalinity of water.

Water molecule (H2O) dissociates into hydroxyl (OH-) and hydrogen (H+) ions.

H2O→ (OH) + (H+)

(H+) x (OH) = 10-14

For pure water

H+= OH = 10-7

pH = 7 (neutral)

pH = -log(H+)

pH is the negative logarithm of H+ ions

If pH < 7 - acidic

If pH > 7 – alkaline

Significance of pH

• Causes incrustation / tuberculation in pipes

• Corrosiveness of water is pH dependent

• Biological activities are pH dependent vd bovome

• Water softening process depends on pH

• Coagulation process depends on pH

Methods to determine pH

a) Colourimetric Method

• Indicator is added to water sample

• Colour of water is compared to standard colours of known pH

• Acidic range indicator - methyl red

• Alkaline range indicator - phenolpthalein red

• Standard colours are in the form of coloured glass disc and coloured charts

(b) Electrometric method

• A PH meter is used. The pH electrode is dipped in the water sample. pH value can be read directly on the dial.

(v) Metals and other chemical substances

(a) Iron and Manganese

• Iron causes hardness, bad taste, discoloration of clothes and plumbing fixtures, heavy growth of crenothrix which leads to pipe clogging.

• Iron can be found by simple calorimetric procedure using thiocyanate and thioglycollic acid.

• Manganese imparts brownish / purplish colour to water and stains plumbing fixtures

• Manganese is found by matching the pink colour produced on oxidation to permanganate. Sodium paraperiodate and ammonium persulphate are used to colour both water sample and manganese colour standards.

(b) Lead and Arsenic

• Lead is a cumulative poison. Prolonged exposure can cause death.

• Concentration of lead should be less than 0.05 mg/l

• Lead is detected by 6 drops of sulphuric acid in water sample; white precipitate formed indicates presence of lead.

• Arsenic causes Chronic poisoning and is difficult to diagnose. Arsenic is removed by ion exchange equipment using activated alumina. Determined by Heteropoly blue colorimetric method by comparing stains on paper strips.

(**c) Fluorides and Iodides**

• Small concentrations of Fluoride and Iodides are useful to human

• Iodine < 1 ppm - prevent goitre.

• Fluoride < 1.2 ppm – prevent dental caries in children

• Excess concentration > 3 ppm - Causes dental fluorosis or mottled enamel

• Fluorides is estimated by colourimetric method ie., by developing a colour with zirconium - alizarin reagent.

• Iodide is determined by its ability to catalyze reduction of ceric ions by arsenious acid.

1.29

(d) Barium and Boron

• Barium is toxic to heart, blood vessels and nerves (Central Nervous System). It may cause 'borism'. Determined by Colorimetric and Titrimetric methods.

• Solution of Carmine acid in concentrated sulphuric acid changes colour from bright red to bluish red or blue depending on the concentration of boron.

(e) Cadmium and Hexavalent Chromium

• Cadmium is toxic. It is discharged from electroplating plants. Cadmium forms red compound with di-phenyl thiocarbzone and this is used for colourimetric determination of cadmium.

• Chromium can cause cancer. It is discharged from chromium plating units. It is determined colourimetrically by reaction with diphenyl-carbazide in acid solution.

(f) Sodium and Potassium

• Human body maintains constant sodium content.

• Excess quantities of sodium causes edema.

• Sodium and potessium is determined by using Flame Photometer.

(vi) Nitrogen and its compounds

Forms of nitrogen

(a) Ammonical nitrogen (free ammonia)

(b) Albuminoid nitrogen

(c) Nitrite nitrogen

(d) Nitrate

(a) Ammonical Nitrogen

• Free ammonia in water indiates presence of organic matter particularly human and animal excreta, and discharge from gas industries.

• Free ammonia is estimated by distillation method using Nessler's Reagent.

(b) Albuminoid Nitrogen

• It is presence indicates organic polluction in water

• It is derived from aquatic plant and animal life.

• Determined by adding potassium permangnate or sulphuric acid to water sample to and boiling to liberate ammonia gas.

(e) Nitrite

• It is an intermediate in the oxidation - reduction process of the Nitrogen cycle.

• Its presence indicates pllution.

• Determined by treating with sulphanilic acid and matching the colour with standard nitrite solution.

(d) Nitrate

• This is the final stage of oxidation of Nitrogen compounds bise mi 560

• The source of nitrate in water is from cultivation, manure and biological activity in soil.

• Excessive nitrate in water causes infant poisoning - Blue Baby syndrome - methae moglobinemia.

• It is determined by matching the colour produced with phenol-disulphonic acid.

(vii) Dissolved Gases

(a) Dissolved Oxygen (DO)

• DO in water is from dissolution of oxygen from the atmosphere and photosynthetic activities by algae and aquatic plants.

• The oxygen dissolution in water is temperature dependant. DO will be less at high temperature.

• DO is required by aquatic plants and fishes.

• Minimum DO that should be present in water is 4 ppm.

• DO is an indicator of the unstable organic matter in water.

• Excess DO causes corrosiveness of water.

• However, if DO is less, it will affect the photosynthetic activity of aquatic plants, and aquatic animals cannot survive without oxygen. The water will become septic and dangerous.

(b) BOD - Biochemical Oxygen Demand

• It is a measure of the oxygen required by micro organisims to oxidize the organic matter in water

• BOD indicates the amount of unstabilised organic matter (pollution) in water.

• In unpolluted waters, BOD will be less than 5 ppm

• BOD test is conducted by incubating ng the water

(c) Carbon dioxide

• CO_2 in water is from atmosphere, decomposing organic waste and underground sources.

• It makes the water corrosive

• This can be reduced by aeration of water

• It is determined by using alkali with phenolphthalein indicator

(d) Hydrogen Sulphide (H_2S)

• Mostly in ground waters; produced by the decomposition of organic matter and by sulphate reducing bacteria.

• It produces rotten egg smell

• It is reduced by aeration

• H_2S is determined by titration with iodine.

3. Biological Characteristics

A contaminated water is a host for micro organisims that may spread water-borne diseases.

Various micro organisms found in water are classified as

(a) Aquatic Plants

Water weeds and algae are of great concern in water supply sources.

Excess growth of algae and weeds causes the following problems:

(i) They infect the lakes and prevent entry of sunlight and oxygen into water.

(ii) They impart objectionable taste, odour and colour.

(iii) Cause turbidity

(iv) Clog the filter beds

(v) Reduces the capacity of canals and pipes

(b) Aquatic animals

• Fishes, amphibians, insects, spiders, snails, earthwarms, protozoans etc.

• Some are resistant to chlorination

• They cause intestinal infections, dysentry etc.

• They also cause clogging of supply pipes.

(c) Fungi, Bacteria and Viruses

• They modify pH of water and produce organic acids and ammonia

• Decomposition or death of fungi imparts disagreeable taste and odour to water.

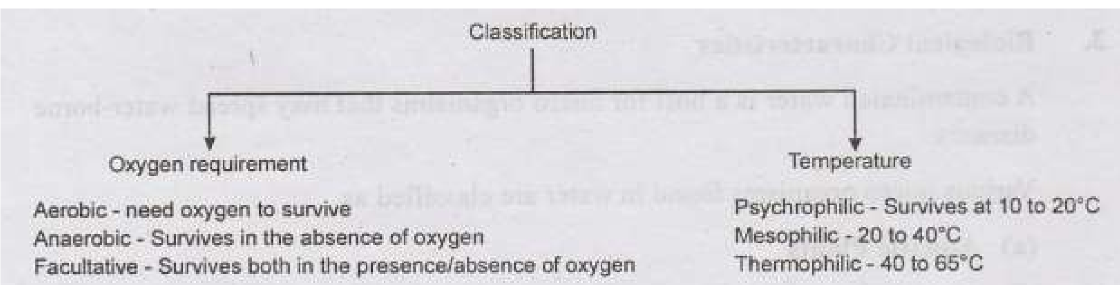
• They are controlled by treatment of water with Chlorine or Copper Sulphate.

Viruses

• They are infections agents and cause waterborne diseases

• Bacteriophages viruses cause respiratory infections in children, Hepatitis, Polio etc.

Bacteria



Bacterias cause typhoid, cholera, dysentry and it is necessary to detect their presence in water.

Different groups of bacteria that are of importance are:

(i) Coli form group / Coli-aerogenes (E.coli)

These bacterias are harmless and are found in the intestines of animals and human beings and are excreted with faeces. But, the presence of these bacteria indicates the contamination of sewage in water and presence of pathogens.

Microbiological investigations are done for E.Coli - Escherichia Coli which is used as the indicator organisms. E.coli is found in the human intestine and is not harmful. But the presence of E.coli in water confirms the presence of other disease causing (pathogens) microorganisms in water.

Purpose of microbiological examination of water

• To detect the degree of pollution in water bodies

• To assess the amount of treatment required to render the water safe.

• To ascertain the efficiency of treatment at various stages.

• To locate the cause of any sudden deterioration in water quality.

Coliform Index or E-coli Index

The number of coliform bacterias present in the water sample is found by the following procedure.

Fermentation tubes are inoculated with varying portions of water sample. The reciprocal of the smallest portion that shows positive result is the coliform Index.

For example: Suppose a test shows the following results:

For example : Suppose a test shows the following results:

10 ml	1 ml	0.1 ml	0.01 ml	0.001 ml
+	+	+	+	−

$$\text{The Coliform Index} = \frac{1}{0.01} = 100 \text{ per ml.}$$

The Most Probable Number (MPN)

MPN is defined as the bacterial density which if it had been actually present in the sample under examination, would more frequently than any other, give the observed analytical result.

MPN is based on probabilities. Standard tables are available to determine MPN for varius combination of test results.

Table 1.4: MPN of organisms per 100 ml of sample using 1 tube of 50 ml and 5 tubes of 10 ml.

No. of positive tubes		MPN per 100 ml	Limits within which MPN per 100 ml can lie	
50 ml tubes	10 ml tubes		Lower limit	Upper limit
0	1	1	< 0.5	4
0	2	2	< 0.5	6
0	3	4	< 0.5	11
0	4	5	1	–
1	0	2	< 0.5	6
1	1	3	< 0.5	9
1	2	6	1	15
1	3	9	2	21
1	4	16	4	40

1. Total Count or Agar Plate Count Test (Colony Count)

Test is done to find the number of bacterial colonies growing on a medium incubated for a specified time at a specified temperature.

The methods use are:

(i) Colony count in nutrient agar after 3 day incubation at 20 to 22°C

(ii) Colony count in nutrient agar after 24 hrs @ 37°C (common)

(iii) Colony count after continuation of 37°C incubation for further 24 hours.

Water sample after suitable dilution is taken in petridish. Molten nutrient agar is added and incubated at 37°C in an incubator for 24 hrs.

Then, bacterial colonies are counted using magnifying glass.

bevis For Potable water; Total Count should not exceed 100 per ml.

2. The Coliform Test

Coliform group includes all aerobic and facultative anaerobic bacteria

Test Techniques are:

(a) Multiple tube fermentation technique

(b) Membrane filter technique

(a) Multiple tube fermantation technique: This consists of three stage tests:

(i) Presumptive test

(ii) Confirmed test

(iii) Completed test

(i) Presumptive test

• Fermentation (Durham) tubes are used

• Measured volume of water sample is taken in two tubes.

• Bite salt lactose broth is added and tubes are incubated at 37°C for 24 to 48 hrs.

• Acid or gas formation after 24 to 48 hrs shows positive test.

• This test alone is not reliable.

• The tubes that gave positive results should be tested further to confirm the ad presence of E.coli.

(ii) Confirmed Test

• The positives tubes from presumptive test are further tested.

• The presumptive culture is placed on MacConkey agar or Eosin-methylene blue agar and incubated at 37°C for 24 hrs.

• The growth of single discrete pure dark red bacterial Colonies results. positive

• Alternatively, the culture can be transferred to another fermentation tube containing brilliant green lactose broth and incubated at 37°C for 48 hrs.

• Formation of gas after 48 hrs shows positive results. amotilos arb

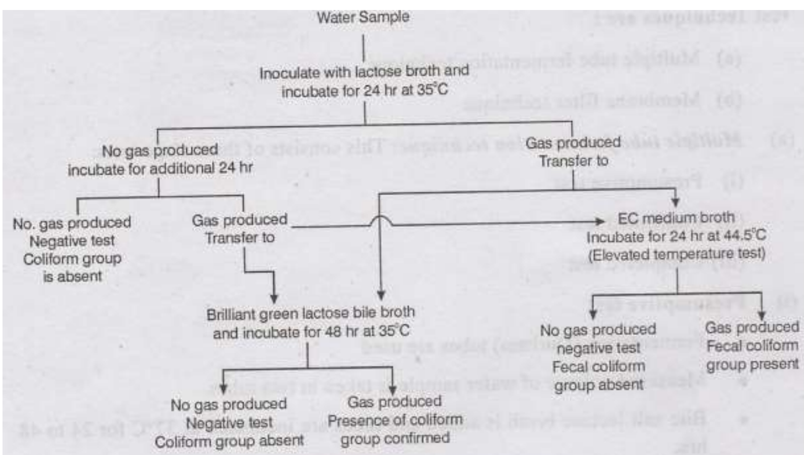


Fig. 1.13 Schematic diagram for Caliform Tests

(iii) Completed test

• Positive tubes from completed test are subject to further testing.

• The Culture is placed on Endo or Eosin methylene blue plates and incubated at 37°C for 24 hrs.

• Typical coliform colonies are transferred to Mac Conkey broth tube and nutrient anelydis agar and incubated at 37°C for 48 hrs. Gas production shows positive results

(b) Membrane filter technique

• High precision technique

• Filter membrane made of cellulose esters with microscopic pores are used.

• The water sample is made to pass through the filter membrane which retains the coliforms.

• The membrane cultures are incubated at 37°C for 20 hours

•The colonies exhibit a metallic luster and are counted under a microscope.

• This test is not suitable for turbid water due to presence.

WATER BORNE DISEASES

Waterborne diseases are illnesses caused by microscopic organisms, like viruses and bacteria, which are ingested through contaminated water or by coming in contact with feces. Water-borne diseases are the ones caused by pathogenic microbes spread via contaminated water.

Transmission of these pathogens occurs while using infected water for drinking, food preparation, and washing clothes, among others. Many developing countries do not have proper water treatment plants, especially in the rural areas. In some places, the availability of water is so scarce that people have neither the time nor the money to afford the water purifiers or other water treatment mechanisms. Majority of water-borne diseases worldwide mainly affect children due to poor hygiene and weak immunity. Most of these diseases are life-threatening. The knowledge of the different types of water-borne diseases has come to the forefront with the advent of globalization over the past few decades. Several pathogenic microorganisms which were previously unknown have become the focus of major research in this field.

❖ Typhoid Fever

Although rare in industrialized countries, typhoid fever is well-known in extremely poor parts of developing nations; it's estimated that up to 20 million people worldwide suffer from the illness each year. It's spread through contaminated food, unsafe water, and poor sanitation, and it is highly contagious.

Symptoms include:

• A fever that increases gradually

• Muscle aches

• Fatigue

• Sweating

• Diarrhea or constipation

Prevention and Treatment:

To prevent dysentery, wash your hands with soap frequently, order all drinks without ice, don't eat food sold by street vendors, and only eat fruits you can peel. Drink only bottled and sealed, and do not eat food from villages or street vendors. Typhoid is treated with antibiotics.

❖ Cholera

Cholera is commonly found in humanitarian emergencies or marginalized villages where poverty and poor sanitation are rampant. The disease is spread through contaminated water and causes severe dehydration and diarrhea. Cholera can be fatal within days or even hours of exposure to the bacteria, but only 1 in 10 people will develop life-threatening symptoms.

Symptoms include:

• Nausea

• Vomiting

• Diarrhea

• Muscle cramps

Prevention and Treatment:

Cholera is a waterborne illness that’s easily prevented when traveling. Wash your hands often, only eat foods that are completely cooked and hot (no sushi), and only eat vegetables you can peel yourself, like avocados, bananas, and oranges. Of course, drink safe water.

❖ Dysentery

An intestinal infection, dysentery is a waterborne disease characterized by severe diarrhea as well as blood or mucus in the stool. Dysentery is good reason to always wash your hands, as the disease is spread mainly through poor hygiene. It can be caused by bacteria, viruses, or parasites in unsafe food and water and by people coming in contact with fecal matter. If someone experiencing dysentery cannot replace fluids quickly enough, their life could be at risk.

Symptoms include:

• Stomach cramps and pain

• Diarrhea

• Fever

• Nausea

• Vomiting

• Dehydration

Prevention and Treatment

To prevent dysentery, wash your hands with soap frequently,order all drinks without ice, don’t food sold by street vendors, and only eat fruits you can peel. Drink only sealed bottled water while traveling in places with higher dysentery risk, such as communities where proper hygiene practices are uncommon. Mild dysentery usually clears up with rest and fluids, but over-the-counter medications such as Pepto-Bismol can help with stomach cramping. More severe cases can be treated with antibiotics, although some strains of the disease are resistant.

❖ Escherichia Coli

E. coli is a bacteria with various strains, some dangerous and some beneficial. For example, E. coli bacteria is important in creating a healthy intestinal tract.

However, if animal waste has found its way into farmland where produce is grown or if strains of E. coli are spread through the process of making ground beef, those who consume these foods could experience symptoms of the waterborne illness. The bacteria are also found in unsafe water sources around the globe where human water sources and cattle coexist.

Symptoms of dangerous strains of E. coli are similar to that of dysentery and other waterborne diseases. Most bouts of E. coli pass within a week, but older people and young children have a greater chance of developing life-threatening symptoms. Anyone believed to have been exposed to contaminated food or water should contact a doctor if diarrhea contains blood.

Prevention and Treatment

As always, avoid water possibly contaminated by human and/or animal feces (like ponds, rivers, and swamps). If you are going to eat ground beef, cook thoroughly. Wash fruits and vegetables well, wash hands often, and drink only safe water.

To treat the disease, drink plenty of safe water, rest, and take over-the-counter diarrheal medication. While these are simple prevention and treatment tips, there are many remote communities in Uganda who have no choice but to drink from swam.

STANDARDS FOR PORTABLE WATER

The water quality standards are suggeted by the following agencies

(i) Indian Council of Medical Research (ICMR)

(ii) World Health Organisation (WHO)

(iii) United States Public Health Society (U.S.P.H.S.)

(iv) American Water Works Association (A.W.W.A)

The Central Public Health and Environmental Engineering Organisation (CPHEEO) the "The Ministry of Urban Development" (MUD) India has prepared the Manual on water supply and treatment in which water quality standards have been laid down.

Taple 1.5: Water Quality Standards

Sl No.	Characteristics	Acceptable	Cause for rejection
1	Turbidity (JTU)	2.5	10
2	Colour (Platinum cobalt scale)	5.0	2.5
3	Taste and Odour	Unobjectionable	Unobjectionable
4	pH	7.0 to 8.5	6.5 to 9.2
5	TDS (mg/l)	500	1500
6	Total hardness ($CaCO_3$ mg/l)	200	600
7	Chlorides (mg/l)	200	1000
8	Sulphates (mg/l)	200	400
9	Fluorides (mg/l)	1.0	1.5
10	Nitrates (mg/l)	45	45
11	Calcium (mg/l)	75	200
12	Mg (mg/l)	>30	150
13	Iron (mg/l)	0.1	1.0
14	Manganese (mg/l)	0.05	0.5
15	Copper (mg/l)	0.05	1.5
16	Zinc (mg/l)	5.0	15.0
17	Phenolic compounds(mg/l)	0.001	0.002
	Toxic		
18	Arsenic (mg/l)	0.05	0.05
19	Cadmium (mg/l)	0.01	0.01
20	Chromium (hexavalent) (mg/l)	0.05	0.05
21	Cyanides (mg/l)	0.05	0.05
22	Lead (mg/l)	0.1	0.1
23	Selenium (mg/l)	0.01	0.01
24	Mercury (mg/l)	0.001	0.001

INTAKE STRUCTURES

Intakes are the structures built in surface water sources (such as rivers, lakes, reservoirs etc.) for the withdrawal of water and discharge into conduits of the water supply schemes.

Different parts of an intake are:

(i) Entry ports or Inlets or Penstocks: Ports are provided at different elevations to ensure water flow during all seasons. i.e. to take care of fluctuation during summer. The lowest entry port is placed below the lowest water level (LWL) of the river so that water is available during dry season also.

(ii) Screens: The entry ports are protected with screens to prevent entry of any debris or floating materials into the intakes.

(iii) Intake well: It is built of masonry or concrete which may be rectangular or circular in shape. Water drawn from the sources through entry ports is stored in these wells which is then discharged through conduits for water supply.

(iv) Conduits : They are the pipelines through which water is conveyed from the intake well to the nearby treatment plant or water supply system.

(v) Gate valves and control room : The water flow is regulated by gate valves provided on top at the control tower.

(vi) Foot bridge: A foot bridge is provided on top of the intake tower for access.

Factors governing the location of site for intakes:

The site chosen for intakes should be preferably

(i) Near the treatment plant

(To reduce the cost of piplines)

(ii) At the purer zone of the surface source

(To reduce the water treatment cost)

(iii) At the upstream side of source

(iv) Not near any waste water or sewage disposal points.

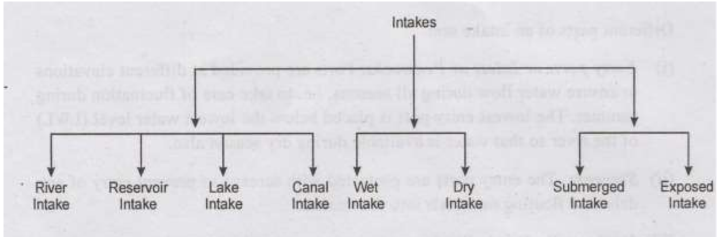
(v) Provide greater withdrawal of water including expansions in future.

(vi) Provide water even during dry seasons

(vii) Not near any navigation channel

(viii) Should not get flooded.

TYPES OF INTAKES



1. River Intakes

• Located on the upstream side of rivers, where pollution is minimum.

• Located inside the river or on river bank such that sufficient water depth is available to meet the demand during dry seasons also.

• Sometimes, weirs are constructed across the rivers to increase the water level.

Classification of river intakes

(i) Twin well type

(ii) Single well type

(i) Twin well type of River Intake Structure

This is the common type of river intake constructed on non-alluvial rivers

The structure consists of

(i) An inlet well

(ii) An inlet pipe

(iii) A jack well

Inlet well or intake well or collector well is of circular built concrete or masonry located on river bed such that water is available during low flows. A foot bridge is provided for access from the river bank. River water enters the inlet

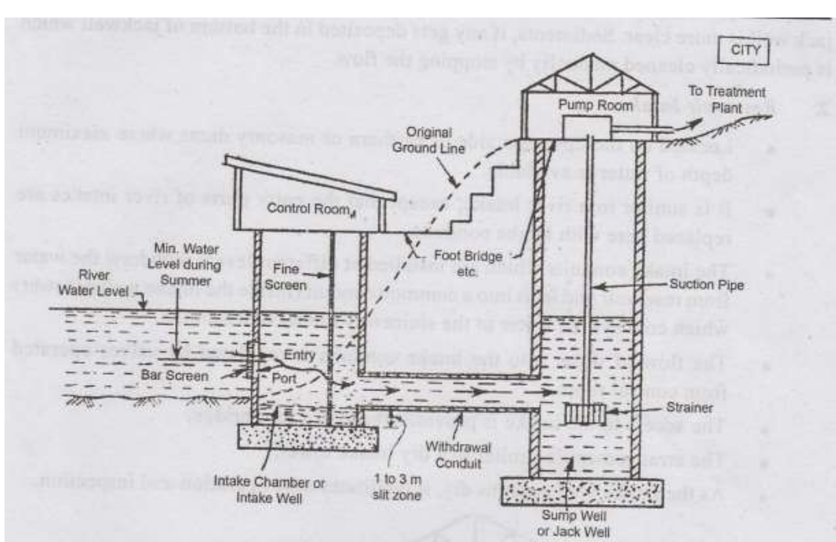


Fig.1.14 River intake (Twin well type)

well through openings or ports provided at various levels and protected by screens to exclude entry of floating debris. The flow into the entry ports is regulated from the control tower using gate valves. The intake well is connected to jack well (sump well) constructed on the river bank, by a RCC intake pipe. The bottom portion of intake well below the level of the intake pipe is used for the accumulation of silt and sediment. The deposited silt is periodically removed either manually or mechanically and it is ensured that the silt does not enter the intake conduits. The pipe is provided at a gentle slope and the flow through the pipe is under gravity at atmospheric pressure. The pipe diameter is chosen based on the discharge capacity. Water entering the jack well is lifted by pumps and fed into the main lines of water supply system.

(ii) Single well type of a River Intake

This type of intake is constructed on alluvial rivers where weirs or approach channels are constructed to increase the water level.

In this intake, there is no separate inlet well or inlet pipe(as in Twin Intake). The opening ports with bar screens are provided in the jack well. Itself. Water entering the jack well is more clear. Sediments, if any gets deposited in the bottom of jackwell which is periodically cleaned manually by stopping the flow.

2. Reservoir Intake

• Located on the upstream side of earthern or masonry dams where maximum depth of water is available.

• It is similar to a river intake, except that the entry ports of river intakes are replaced here with intake conduits.

• The intake conduits which are installed at different levels withdraw the water from reservoir and let it into a common conduit (inside the intake well or tower) which conveys the water to the sluiceway tunnel downstream.

• The flow of water into the intake conduits is regulated by valves operated from control room.

• The access to the intake is provided through a foot bridge.

• The arrangement is similar to a dry intake tower.

• As the intake well remains dry, it facilitates easy operation and inspection.

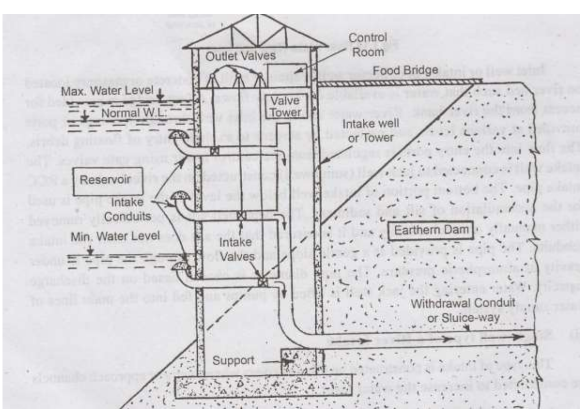


Fig.1.15 Reservoir Intake

3. Lake Intake

• Similar to reservoir intakes if the water depth is reasonable

• At shallow waters, Lake intakes are provided as submerged intakes.

• Submerged intakes are constructed as cribs or bell mouths.

• The cribs are made of heavy timber framework with cast iron or mesh grating on top. It protects the intake conduit from damage.

4. Canal Intake

• The intake well is located in the bank of canal.

• The water enters the intake well through a port protected with coarse screen, provided at minimum water level in the canal.

• The water from the chamber is then conveyed through a outlet (withdrawal) conduit to the distribution system.

• The inlet end of the outlet conduit is of bell mouth shape protected with a fine screen.

• An outlet valve is provided to control the flow which is operated from top.

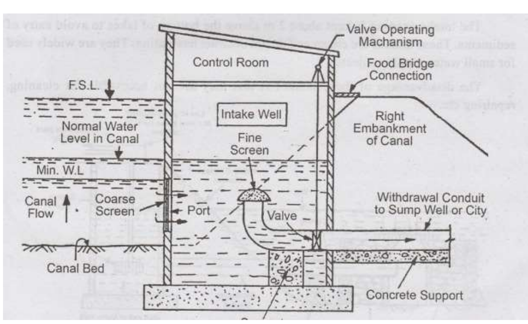
• The flow through the outlet pipe may be under gravity or by pumping.

Fig.1.16 Canal Intake

5. Submerged Intake

• Such intakes are placed in streams or lakes where there are deep waters and very less sediments.

• This consists of a simple concrete block or a rock filled timber crib supporting the starting end of the withdrawal pipe. The intake opening is protected by screen.



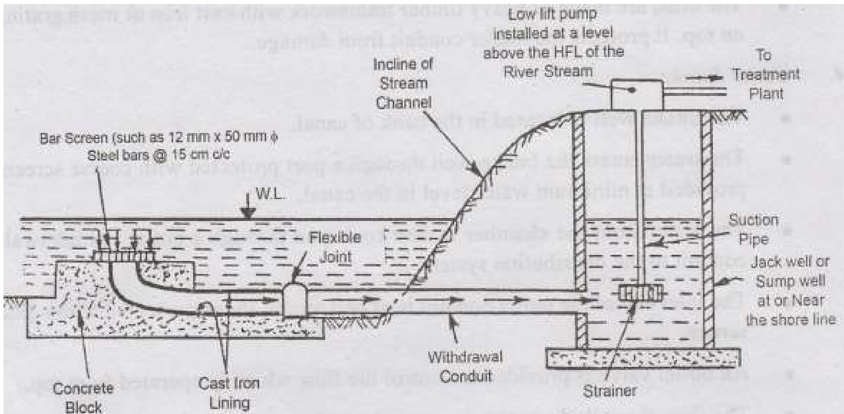


Fig.1.17 Simple concrete block submerged intake

The intake opening is kept about 2 m above the bottom of lakes to avoid entry of sediments. These intakes are cheap and do not obstruct navigation. They are widely used for small water supply projects.

The disadvantage of these intakes is that they are not accessible for cleaning, repairing etc.

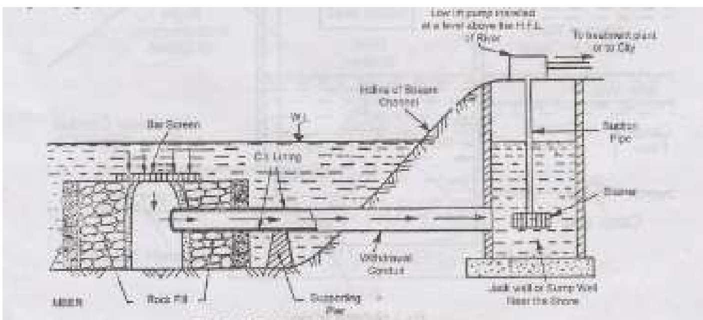


Fig. 1.18 Rock filled timber crib-submerged Intake

INTAKE TOWERS

Types of Intake towers:

(i) Wet intake tower

(ii) Dry intake tower

(i) Wet Intake Towerse

• In wet Intake Towers, water is filled in both the intake well (chamber) and the conduits.

• It consists of a concrete circular shell filled with water and vertical inside shaft connected to the withdrawal pipe.

• Openings (Ports) are provided in the concrete shell as well as the vertical shaft for the entry of water. The flow is regulated by gate valves.

• Water from the withdrawal pipe flows to the nearby water treatment plant either under gravity or by pumping.

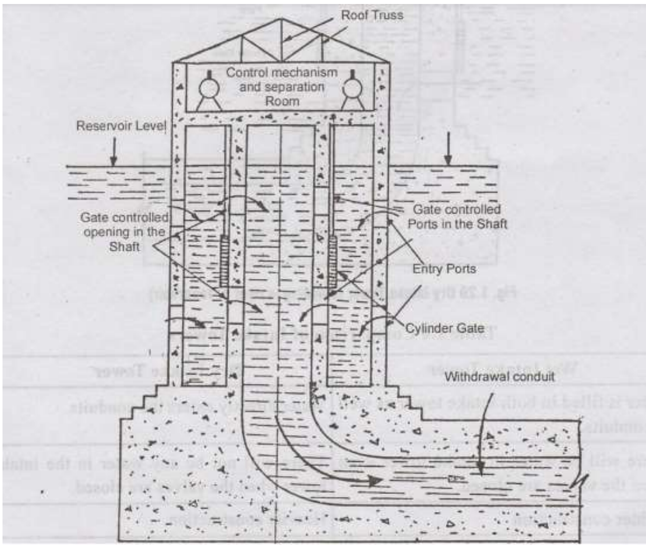


Fig. 1.19 Wet Intake Tower(Standing in river or resservoir)

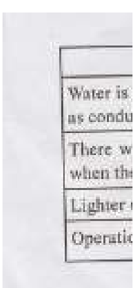
(ii) Dry Intake Towers

• In dry intake towers, water is directly drawn into withdrawal conduits through gated entry ports.

• There will be no water in the tower.

• Heavier construction is required than the wet intake towers.

• (It facilitates easy operation and maintenance.



Types of conduits

Depending upon the flow conditions, the conduits are categorised as

(1) Gravity conduits

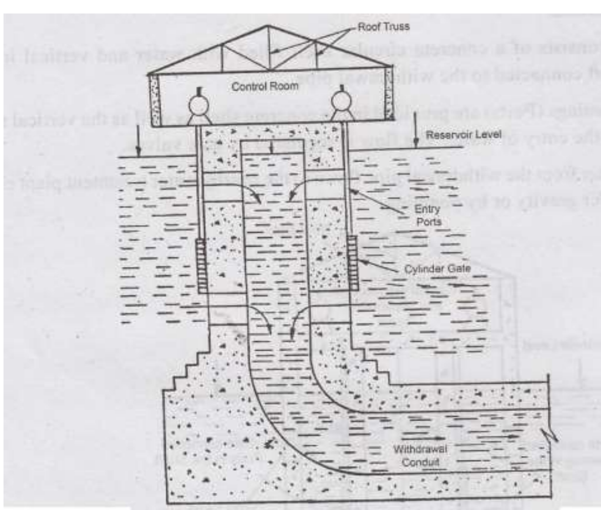


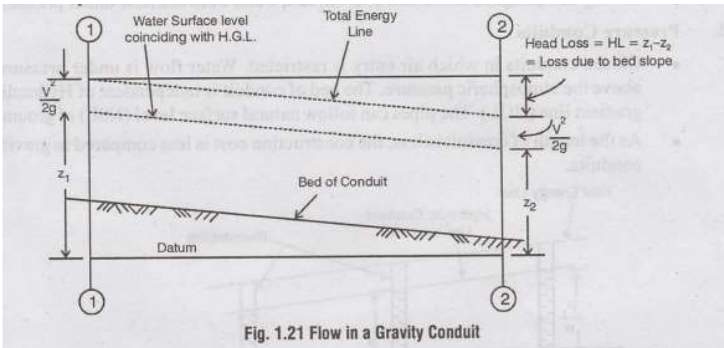
Fig. 1.20 Dry Intake Tower (standing in river or reservoir)

(2) Pressure Conduits

(1) Gravity conduits / Open channels

• Water flows under gravity at atmospheric pressure

• The hydraulic gradient line will coincide with the water surface and will be parallel to bed of conduits.



• Conduits are provided at gradual slope. They cannot follow the natural surface level.

• The length of conduit is more which increases the cost of construction.

• In order to maintain the HGL, these conduits have to be taken on trestles constructed across Valleys/depressions. It further increases the cost.

• The advantage is that no pumping is required.

Different forms of gravity conduits are:

(i) Canals

(ii) Flumes

(iii) Aqueducts

Canals:

• Open channels constructed by cutting high ground and filling low grounds.

• They are lined or unlined depending upon the slope/velocity/ water quality / losses.

Flume:

• Open channels supported above ground over trestles.

• Used to convey water across valley or depressions or obstructions

• Made of masonry, RCC, metal, wood

• Usually regtangular or circular in cross-section

Aqueducts:

• Closed, rectangular or circular or horse shoe section

• Built of Masonry or RCC.

• Usually covered/closed.

• As they are designed to run half or 3/4th full, water does not flow under pressure

2. Pressure Conduits

• Closed conduits in which air entry is restricted. Water flow is under pressure above the atmospheric pressure. The bed of conduit is independent of Hydraulic gradient line (HGL). The pipes can follow natural surface level (NSL) of ground

• As the length of conduit is less, the construction cost is less compared to gravity conduits.

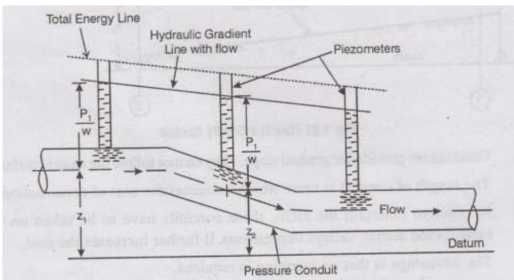


Fig. 1.22 Flow in a pressure conduit

• As pressure conduits follow the natural surface level, deep excavations are n required (as in the case of gravity conduits which follow HGL) and therefore is economical. But in depressions, pumping may be required to achieve pressu flow which increases the cost.

• Pressure conduits may be in the form of pressure aqueducts/pressure tunne preferably circular in shape.

• As the conduits are closed, there are less chances of water pollution.

TWO MARK QUESTION AND ANSWERS

1. What are the objectives of water supply scheme?

(i) To supply safe and wholesome water to consumers

(ii) To supply water in adequate quantity

(iii) To make water easily available for encouraging personal and household cleanliness.

2. Enumerate the components of a water supply scheme.

Collection works (intake structures), Treatment works (sedimentation tanks, sand filters), Transmission works (pipelines), Distribution works (storage reservoirs, pumps).

3. What is Design Period?

The future period for which provision is made in the water supply scheme or for which the components of a water supply system are designed is called as design period. Normally it is considered as 20 to 40 years. Eg: Design period for storage dams - 50 years, water treatment units - 15 years.

4. What are the factors governing the design period?

The design period is chosen based on the following criteria:

i) Useful life of pipes, equipment and structures.

ii) The anticipated rate of growth. If the rate is more, design period will be less.

iii) Availability of funds. The rate of interest on borrowing and the additional money invested.

iv) Efficiency of component units. The more the efficiency, the longer will be design period.

5. What are the methods of population forecasting?

• Arithmetic increase method

• Geometric increase method

• Incremental increase method

• Simple graphical method

• Master plan or zoning method

• Logistic curve method

6. What are the assumptions in an Arithmetical Increase Method to forecast population?

The increase in population from decade to decade is assumed constant ie., rate of change in population dP/dt is constant.

7. What are the assumptions in an Geometrical Increase Method to forecast population?

The percentage increase in population from decade to decade is assumed constant

8. List out the various water demand encountered in society?

• Residential or Domestic demand, • Industrial Demand, • Institutional Demand

• Commercial demand, • Fire demand,

• Demand for Public Use. • Water losses

9. What are the factors affecting per capita demand?

The factors affecting the per capita demand are :

• Climatic conditions

• Size of city

• Quantity of water

• Pressure in supply

• System of supply

• Cost of water

10. Mention the various sources of water supply?

Surface water sources - Lakes, Ponds, Streams & Rivers, Impounding Reservoirs

Sub surface sources — Springs infiltration galleries infiltration wells wells tube.

11. Distinguish between Shallow and deep well?

Shallow well

• A shallow well is one where the source of water is an (410 primary unconfined aquifer

• Yield of shallow wells is comparatively less

Deep well

• A deep well is one which is having water supply from a confined aquifer

• Yield of deep wells is more than shallow wells

12. What are springs? What are the types of springs?

The natural outflow of ground water at the earth surface is called as springs.

Gravity springs, Surface springs and Artesian springs.

13. What are the factors governing the selection of a particular source of water?

• Quantity of available water

• Quality of available water

• Distance of the source of supply to the distribution area

• General topography of the intervening area.

• Elevation of the source of supply.

14. State the purpose of carrying out water quality characterization?

• To determine the physical, chemical and biological characteristics of surface and ground water sources

• To analyze whether the water quality parameters meet the Standards laid by legislative authorities.

• To recommend suitable water treatment methods.

• To determine the efficiency of the treatment methods

• To supply safe and wholesome water to the consumers

15. Give the maximum acceptable limit of the following for the public drinking water (a) Colour (b) pH (c) Chlorides (d) Sulphates

Colour - 5,

pH - 7 to 8.5

Chlorides - 200 mg//l

Sulphates - 200 mg/l

16. What are the acceptable quality standards as per BIS 10500: 1983 for flouride and nitrates?

Flourides - 1 mg/l, Nitrates - 45 mg/l

17. What is an intake?

The intake or intake works comprises of a structure placed in a surface water source to permit the withdrawal of water from the source and then to discharge into an intake conduit through which it will flow into the water supply system.

18. Brief the function of intake structure?

• The main function of intakes is to provide highest quality of water from source.

• To protect pipes and pumps from damaging or clogging by wave action, floating bodies and submerged aquatic lives

• To help in safely withdrawing water from the source over predetermined pool levels and then to discharge this water into the withdrawal conduit

19. What are the types of intake according to their position?

• River Intake

• Reservoir Intake

• Lake Intake

• Canal Intake

* Submerged Intake

* Exposed Intake

20. Differentiate between Wet Intake and Dry Intake?

Wet Intake

In this intake structure, water is found in the intake tower (well) as well as the intake conduit.

Difficult to do inspection and repair works.

Dry Intake

In this intake structure, water enters only inside the intake conduits. The intake well or tower is dry.

Easy inspection and repair.

21. What are the factors governing the location of intake?

• It should be nearer to the treatment plant

• It should never be located near the sewage disposal points

• Water should be available even during the worst conditions

• Located on the upstream of rivers

• It should not be located near the navigation channel

UNIT - II

WATER TREATMENT

OBJECTIVES OF WATER TREATMENT

The objectives of water treatment are:

(i) To remove objectionable colour of water

(ii) To remove unpleasant taste and odour

(iii) To remove dissolved gases in water

(iv) To remove suspended, colloidal and dissolved impurities in water

(v) To remove hardness of water

(vi) To reduce corrosiveness of water

(vii) To remove the disease producing micro organisms (pathogens) from water.

(viii) To make water suitable for domestic and industrial purposes.

UNIT OPERATIONS AND PROCESSES

Unit Operations: Treatment done by physical or mechanical methods are called as unit operations.

Eg: Screening, Filtration, Sedimentation etc.

Unit Processes: Treatment done by employing chemical or biological methods are called as Unit Processes.

Eg: Coagulation, Chlorination etc.

The important unit operations employed in water and waste water treatment are:

1. Gas transfer: Aeration

Water is exposed to oxygen, to remove dissolved harmful gases (CO_2, H_2S) and Iron-Manganese from water. Aerators may be Gravity aerator, spray aerators, diffusers etc.

2. ION Transfer

(i) Chemical coagulation - Removal of colloidal particles - Coagulant is added to water to form clusters which settle rapidly.

(ii) Chemical precipitation - Chemicals are added to precipitate out the dissolved impurities. Eg: Precipitation of carbonate hardness by adding lime.

(iii) Ion exchange - Interchange of ions between water and solid ion exchange media. Eg: Water softening process.

(iv) Adsorption - Ions are removed from solution and concentrated at surfaces of adsorbent. Eg: Activated carbon adsorption.

3. Solute stabilization

Water is stabilised and objectionable solutes are converted into unobjectionable forms.

(i) Chlorination - H_2S is oxidised into sulfate

(ii) Liming-CO_2 is converted to soluble bicarbonate by passing through limestone.

4. Solids transfer.

Removal of solids from water.

(i) Straining - Removes floating and suspended impurities using Screens.

(ii) Sedimentation - Removal of suspended solids in settling tanks under gravity.

(iii) Floatation - Suspended solids gets attached to floatation agents that lift the particles to surface - removed by floatation devices.

(iv) Filtration - Suspended solids are trapped on the grains of filter media (sand, coal, granular materials)

5. Nutrient or Molecular Transfer

6. Interfacial contact

7. Miscellaneous operations:

(i) Disinfection - Removal of pathogens from water

(ii) Desalination - Convertion of salt water into fresh water

(iii) Fluoridation - Adding fluoride to water

8. Solids concentration and stabilization – Used in waste water (sludge) treatment to increasw the soilds concebtration of sludge.

(i) Thickening

(ii) Centrifuging

(iii) Sludge digestion

AERATORS OF FLASH MIXERS

• It is an important unit operation of gas transfer.

• In this process, water is brought in intimate contact with air, so as to absorb oxygen and to remove carbon dioxide gas.

Objectives of aeration are:

(i) It removes tastes and odours caused by gases due to organic decomposition.

(ii) It increases the dissolved oxygen in water.

(iii) It removes the hydrogen sulphide and odour produced.

(iv) It decreases carbondioxide of water thereby reduces its corrosiveness and raises its pH value.

(v) It converts iron and manganese, from soluble and insoluble state so that these can be precipitated and removed.

(vi) It kills bacteria to some extent.

(vii) It helps in mixing of chemicals.

Types of Aerators :

The aeration of water can be carried out in the following ways:

1. Spray Nozzles: In this method, water is sprinkled in air or atmosphere through special nozzles which breaks the water into droplets, thus permitting the escape of dissolved gases. It requires considerable head of water (0.75 to 1.5 kg/cm2) required for the working of nozzles. The nozzles function efficiently at a pressure of 10 to 14 m head of water. The carbon dioxide gas is removed upto 90%.

2. Cascade aerators: It is the simplest form of gravity or free fall aerator. Weirs and waterfalls of any kind are cascade aerators. A simple cascade consists of a series of three or ten steps of concrete or metal. Water is made to fall through a certain height (1 to 3m) over a series of steps, and due to this it comes into close contact with air (atmospheric oxygen). These aerators take large quantities of water in a comparatively small area at low head. They are simple and easily cleaned. They are made of robust and durable materials with a long life. The plates are made of cast iron, RCC, timber or glass. The aerators are preferably installed in open air, or may be in a room which has plenty of louvered air inlets. The cascade aerators are efficient in raising dissolved oxygen content of water, but CO, removal is only in the range of 60 to 70%.

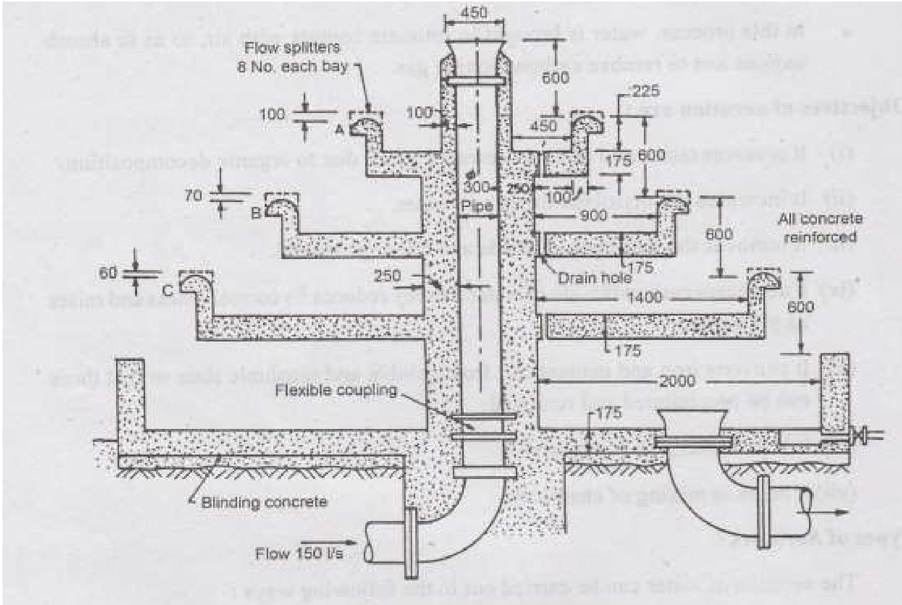


Fig. 2.1 Circular Cascade Aerator

3. Air diffusion: In this method, perforated pipe network is installed at the bottom of the aeration tank, and compressed air is blown through these pipes. The vino compressed air is bubbled up from the bottom of the tank. As the air bubbles olqu bovou travel upward, it gets thoroughly mixed up with the water in the tank, thus causing aeration. Air diffuser basins have a retention period of about 15 minutes and a depth of 3 to 5 metres.

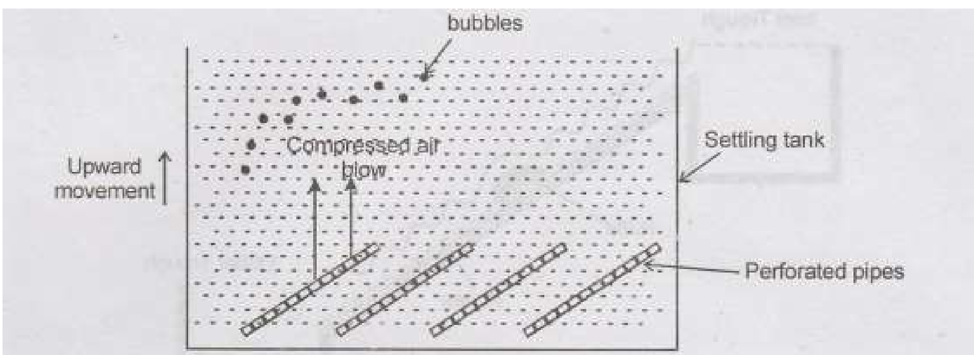


Fig. 2.2 Diffused Aeration

4. Trickling beds (Gravel bed aerators): In this method, the water is allowed to trickle down the beds of coke, limestone or anthracite supported over the perforated bottomed trays, arranged vertically in series. Generally, three beds are used, the depth of each being about 0.6m with a clear distance of about 0.45m inbetween. The water is applied from the top through perforated distribution pipes and allowed to trickle down, up to the bottom bed. During this downward motion, the water gets mixed up with air, and aeration takes place. The size of the coke used ranges between 50 to 75mm. This method is better than cascades, but less effective than spray nozzles. This method is more efficient in CO, removal than other methods.

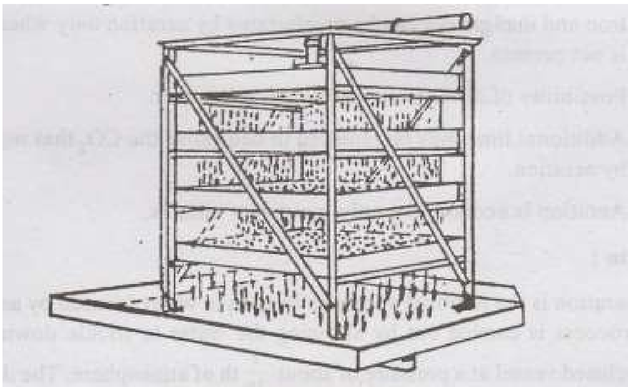


Fig. 2.3 Trickling bed aeration

5. Inclined apron aerator with riffle plates: In this type of aerator, water is allowed to fall along an inclined plane or apron which is usually studded with riffle plates in herring bone fashion. The breaking up of the sheet of water will cause agitation of water and

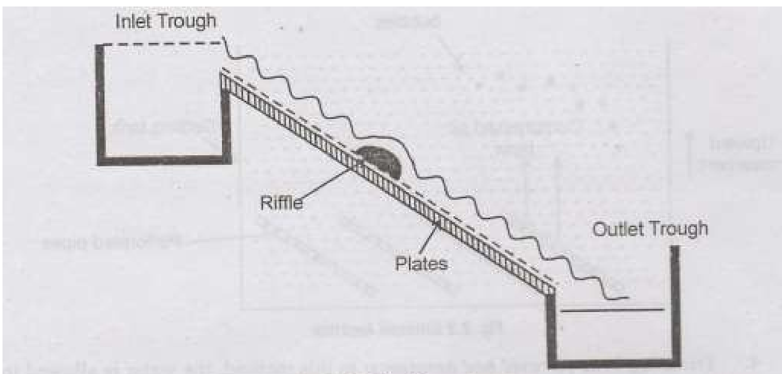


Fig. 2.4 Inclined Apron Aerator

Limitations of Aeration :

Aeration has the following limitations :

(i) It is not an efficient method of removal or reduction of tastes and odours caused by chemical released from industrial wastes.

(ii) Aeration may add more oxygen in water making it more corrosive and may necessiate de-aeration.

(iii) Iron and manganese can be precipitated by aeration only when organic matter is not present.

(iv) Possibility of air borne contamination in water.

(v) Additional lime may be required to neutralise the CO, that would be removed by aeration.

(vi) Aeration is economical only in warmer months.

De-aeration :

De-aeration is the removal of excess oxygen in water (caused by aeration). The de- aeration proccess is carried out by allowing the water to trickle down through gravel layers in a closed vessel at a pressure of about 1/30th of atmosphere. The dissolved oxygen can also be removed by chemical methods or by boiling.

Coagulation and Flocculation

The very fine suspended and colloidal particles in water do not settle under gravity In plain sedimentation thanks. Such particles can however, be removed by increasing their size and mass i.e., by changing them into flocculated particles. To achieve this chemicals called coagulants. are added to water which forms gelatinous precipitate called ‘floc’. Most of the colloidal particles in water are negatively charged. The coagulants (positive charge) neutralize the negatively charged colloidal particles and allow them to coagulate (agglomerate) and form a gelatinous precipitate called ‘floc’ to which more and more particles get attracted and absorbed, forming bigger sized flocculated particles. The flocculated particles due to increase in size and mass readily settles in the sedimentation tanks. The chemically assisted sedimentation process also known as clarification comprises of following three stages:

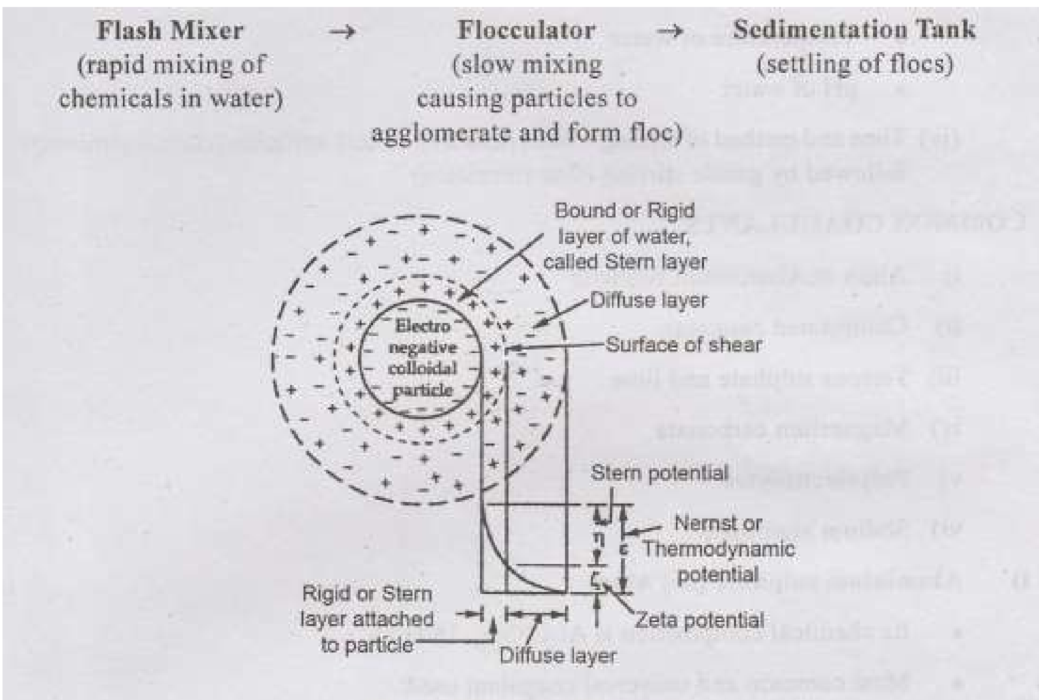


Fig.2.5 Model of a Colloidal particle

(i) Addition of measured quantities of chemicals (coagulants) to water and thorough mixing is done in a Flash Mixer.

(ii) Formation of precipitate which coagulates and forms floc which happens in a Flocculator.

(iii) Settling of flocs in a Sedimentation Tank.

Coagulation is the first stage which refers to the formation of precipitate and destabilisation of charged colloidal particles.

Flocculation - is the second stage which refers to the slow mixing technique promoting agglomeration of stabilised particles.

Factors affecting coagulation:

(i) Type of coagulant,

(ii) Quantity or dose of coagulant

(iii) Characteristics of water.

• Type and quantity of suspended matter.

• Temperature of water

• pH of water

(iv) Time and method of mixing – short period of violent agitation (chemical mixing) followed by gentle stirring (floc formation)

COMMON COAGULANTS

i) Alum or Aluminium sulphate

ii) Chlorinated copperas

iii) Ferrous sulphate and lime

iv) Magnesium carbonate

v) Polyelectrolytes

vi) Sodium aluminate

i) Aluminium sulphate (or) Alum

• Its chemical composition is $Al_2(SO_4)_3\ 18\ H_2O$

• Most common and universal coagulant used.

• It requires presence of alkalinity in water to form floc. Many waters have bicarbonate alkalinity.

Alum dissolved in water, hydrolyze into Aluminium Hydroxide (insoluble – floc)

i) Aluminium sulphate (or) Alum

• Its chemical composition is $Al_2(SO_4)_3\ 18\ H_2O$

• Most common and universal coagulant used.

• It requires presence of alkalinity in water to form floc. Many waters have bicarbonate alkalinity.

Alum dissolved in water, hydrolyze into Aluminium Hydroxide (insoluble – floc)

$Al_2(SO_4)_3\ 18H_2O + 3Ca(HCO_3)_2 = 2\ Al(OH)_3\downarrow + 3CaSO_4 + 18H_2O + 6CO_2\uparrow$ The Aluminium Hydroxide floc so formed is insoluble in water.

Limitations of using Alum :

(i) CO_2 formation leads to corrosiveness in water.

(ii) Calcium sulphate formed causes permanent hardness in water.

If water is not naturally alkaline, lime CaO or hydrated lime $Ca(OH)_2$ is added to

$Al_2(SO_4)_3 . 18H_2O + 3Ca(OH)_2 = 2AI(OH)_3 + 3CaSO_4 + 18H_2$

Sodium carbonate or soda ash can also be added to increase alkalinity.

$Al_2(SO_4)_3 . 18H_2O + 3Na_2CO_2 = 2A/(OH)_2 + 3Na_2SO_4 + 3CO_2 + 18H_2$

Soda ash does not cause hardness, but it is expensive than lime and is used less. Alum is effective at pH 6.50 to 8.50

Alum Dosage - 10 to 30 mg/litre of water. Its dosage depends upon turbidity, colour, taste, pH and temperature.

Alum reduces turbidity, taste and odour. It produces crystal clear water. It is cheap and commonly used. But it is difficult to dewater the sludge formed.

ii) Chlorinated copperas

Hydrated ferrous sulphate is called copperas ($FeSO_4 . 7H_2O$)

• It has high solubility.

• It is used after oxidation to ferric sulphate [$Fe_2(SO_4)_3$] and ferric chloride ($FeCl_3$) by mixing with feed from a chlorinator. The ferric sulphate and ferric chloride are called chlorinated copperas.

$6FeSO_4 . 7H_2O + 3Cl_2 = 2Fe_2(SO_4)_3 + 2FeCl_3 + 7H_2O$

Chlorinated copperas form ferric hydroxide floc.

$Fe_2(SO_4)_3 + 3Ca(OH)_2 = 3CaSO_4 + 2Fe(OH)_3$

$2FeCl_3 + 3Ca(OH)_2 = 3CaCl_2 + 2Fe(OH)_3$

They are effective in removing colour also.

Ferric chloride (ferrichlor) is effective over pH 3.5 to 6.5 and above 8.5

Ferric Sulphate (Ferrisul) is effective over pH 4 to 7 and above 9.

iii) Ferrous Sulphate (Copperas) and Lime

Lime is added with ferrous sulphate to increase the reaction rate.

$FeSO_4\ 7H_2O + Ca(OH)_2 = Fe(OH)_2 + CaSO_4 + 7H_2O$

Ferrous hydroxide Fe(OH), - floc formed is soon oxidised by dissolved oxygen in water and ferric hydroxide Fe(OH), is formed.

$4Fe(OH)_2 + O_2 + 2H_2O = 4Fe(OH)_3$

The ferric hydroxide is a heavier floc.

Ferrous sulphate is effective at pH range above 8.5

iv) Magnesium Carbonate and Lime

When Magnesium Carbonate and Lime are dissolved in water, magnesium hydroxide and calcium carbonate are formed. Both Mg(OH), and CaCO3 are soluble in water resulting in formation of sludge which is a slurry.

MgCO3 + Ca(OH)2 Mg(OH)2 + CaCO3

Due to slurry formation, it is not commonly used. However, it removes organic colour, iron and manganese.

v) Polyelectrolytes

Polyelectrolytes are high molecular weight water-soluble polymers.

They are anionic, cationic or non-ionic. The dosage is 1 ppm.

Cationic polyelectrolytes are available under trade names Floccal N, Magnifloc972, Mogu1980 and are used independently.

Other polyelectrolytes are used as coagulant aids with alum in order to reduce the amount of primary coagulant required.

vi) Sodium Aluminate

Sodium Aluminate Na2Al2O4 is alkaline and used less due to high cost. It removes both temporary and permanent hardness.

The effective pH range is 6 to 8.50. Its reaction with Calcium and Magnesium salts are as under:

$$Na_2Al_2O_4 + Ca\,(HCO_3)_2 = CaAl_2O_4 + Na_2CO_3 + CO_2 + H_2O$$

$$Na_2Al_2O_4 + CaCl_2 = CaAl_2O_4 + NaCl$$

$$Na_2Al_2O_4 + CaSO_4 = CaAl_2O_4 + Na_2SO_4$$

Comparison of Alum and Iron salts (as coagulants)

(i) Iron salts produce heavy floc due to which more suspended matter is removed than with alum.

(ii) Iron salts are good oxidising agents and remove H2S and its corresponding taste and odour.

(iii) Iron salts are effective over wide pH range.

(iv) Iron salts cause staining and growth of iron bacteria in distribution system.

(v) Iron salts impart more corrosiveness to water than alum.

(vi) Skilled suspension is required for handling and storing of iron salts, as they are corrosive. No such supervision is required for alum.

(vii) The time required for floc formation and settling using iron salts is much less.

(viii) Formation of mud balls with iron salts is less compared with alum.

Alum is preferred as coagulant for treating raw waters

Problem 2.1:

Determine the quantity of alum required in order to treat 13 million litres of water per day at a treatment plant, where 12 ppm of alum dose is required. Also determine the amount of CO2 gas which will be released per litre of water treated.

Solution:

Quantity of water to be treated = 13 × 106 litres/day

Alum dose required = 12 ppm = 12mg/1

Amount of alum required per day = (13 x 106) x 12 mg = 156 kg.

Chemical reaction involved is given by:

$$Al_2(SO_4)_3 \cdot 18H_2O + Ca(HCO_3)_2 \rightarrow 2Al(OH)_3\downarrow + 3CaSO_4 + 18H_2O + 6CO_2\uparrow$$

Molecular weight of alum [$Al_2(SO_4)_3 \cdot 18H_2O$

$$= 2(26.97) + 3\,(32.066 + 4 \times 16) + 18(2 \times 1.008 + 16)$$

$$= 666$$

$$\left[\because Al = 26.97,\ S = 32.066,\ O = 16,\ H = 1.008,\ C = 12.01\right]$$

Molecular weight of carbondioxide (CO_2) = (12.01) + 2 × 16 = 44.01 = 44

666 mg of alum $\rightarrow$ release 6 × 44 mg of CO_2

Since 1 mg of alum releases 6 mg CO_2

$$12 \text{ mg of alum will release } = \frac{6 \times 44}{666} \times 12 \text{ mg of } CO_2$$

$$= 4.76 \text{ mg.}$$

Quantity of alum required per day = 156 kg

Quantity of CO_2 released per litre = 4.76 mg

CLARIFLOCCULATOR

The constituents of a coagulation sedimentation plant or Clarifloccculator are:

(1) Feeding device

(2) Mixing device or mixing basin

(3) Flocculation tank or flocculator

(4) Settling or Sedimentation tank

A Clariflocculator containing all these four units is shown in figure

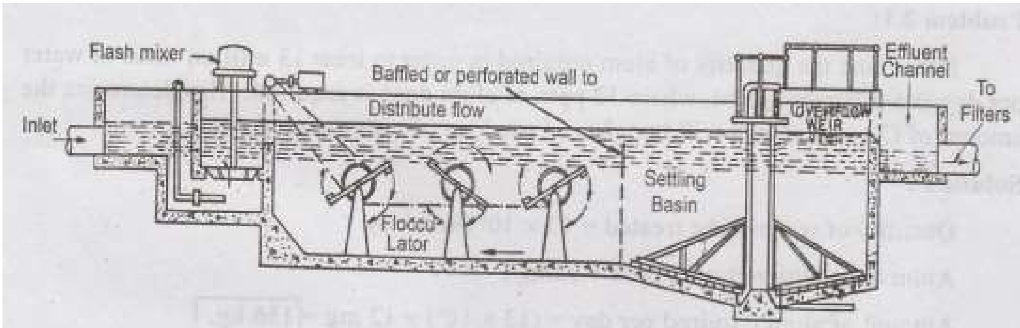


Fig. 2.6 Dorr Clariflocculator

The chemical coagulant is fed (either dry or solution) into raw water through the feeding device.

The (water + coagulant) mixture is thoroughly mixed and agitated in the Mixing

The coagulant causes the very fine suspended and colloidal particles to agglomerate and form ‘floc’, which happens in the flocculation tank.

The flocculated water is finally passed into the sedimentation tank where these flocculated particles settle and are removed.

Each of these four units is discussed in detail below:

1. Methods of feeding coagulants / Feeding devices

a) Dry feeding

b) Wet feeding

a) Dry feeding

The chemical coagulant is fed into raw water in powdered form.

Simple in operation, requires less space and cheaper. However dosage control is difficult. Coagulant (powder) is kept in hopper bottom of tank. Agitating plates prevent arching of coagulant. The dosage is regulated by the speed of toothed wheel/helical screw which in turn is controlled by venturi device installed in the raw water pipes.

The quantity of coagulant released is in proportion to the quantity of the raw water entering the mixing tank.

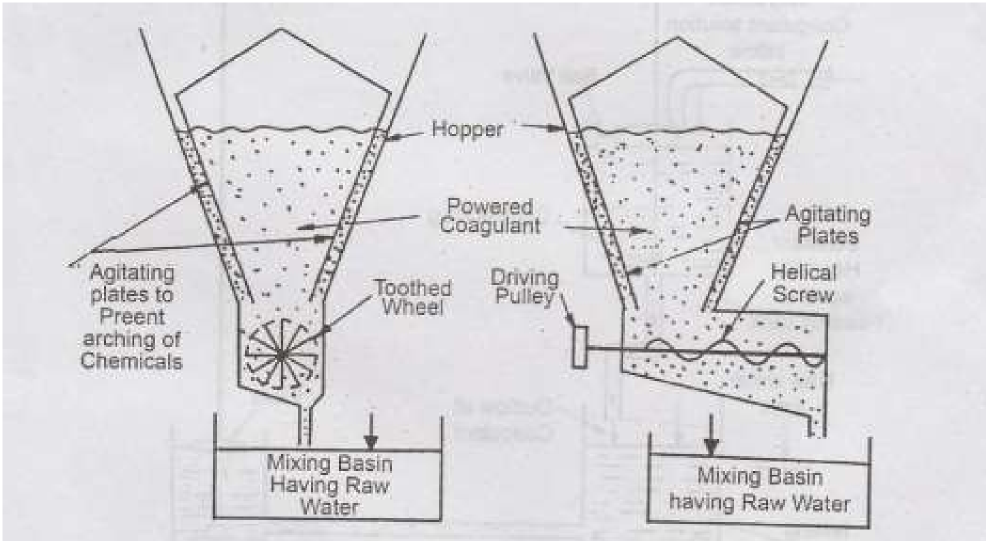


Fig. 2.7 Methods of dry feeding

(**b) Wet feeding**:

The chemical coagulant is fed into raw water in solution form. The wet feeding equipments are costlier, but they can be easily controlled and adjusted. The coagulant solution is prepared and stored in a tank, from where it is allowed to trickle down into mixing tank. A conical plug type arrangement is used to regulate the rate of coagulant discharge proportionate to the rate of raw water flow. The mixing basin and float chamber are interconnected so that water level is same in both. As the flow of water increases, the depth of water in mixing basin as well as float chamber increases and thereby lifting the float. As float rises, the pinion and pulley lifts the conical plug allowing more flow of coagulant solution into mixing basin. When water flow decreases, conical plug descends down and reduces the coagulant feeding rate. Thus coagulant dosage is automatically controlled. The chemical which are corrosive in nature create problems in wet feeding.

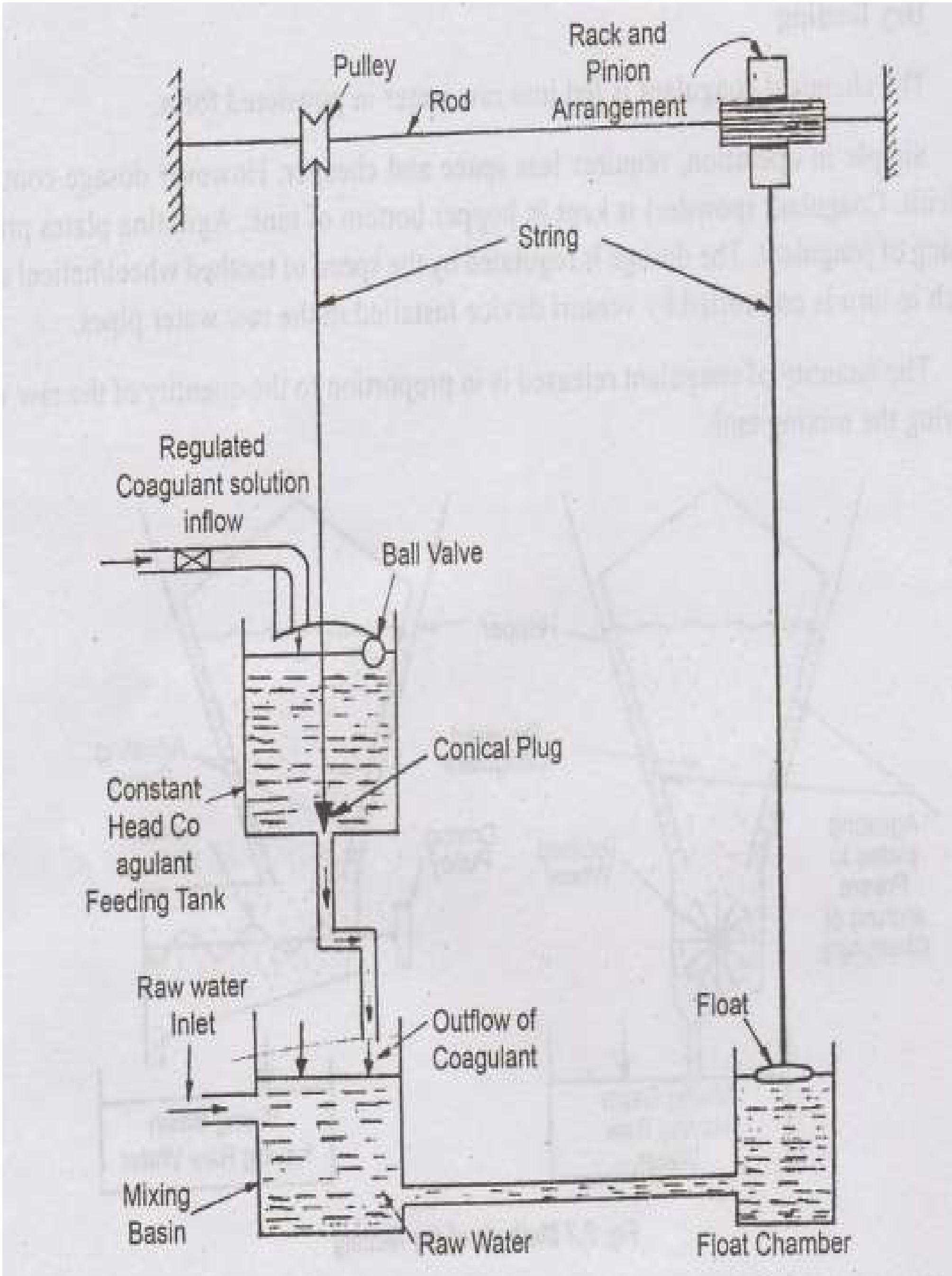


Fig. 2.8 Wet feeding by conical plug and float arrangement.

2. Mixing Devices

After addition of coagulant to raw water, the mixture should be thoroughly and vigorously mixed so that the coagulant gets fully dispersed into water. This violent agitation is achieved by mixing devices such as centrifugal pumps, compressed air and mixing basins. The mixing basins are normally adopted and they are of the following two types:

a) Mixing basins with baffle walls

b) Mixing basins equipped with mechanical devices

(a) Mixing basins with baffle walls: Rectangular tanks which are divided by baffle walls. The baffles are provided in such a way that the water flows in the following pattern.

(i) Horizontally around the ends of baffles.

(ii) Vertically over and under the baffles.

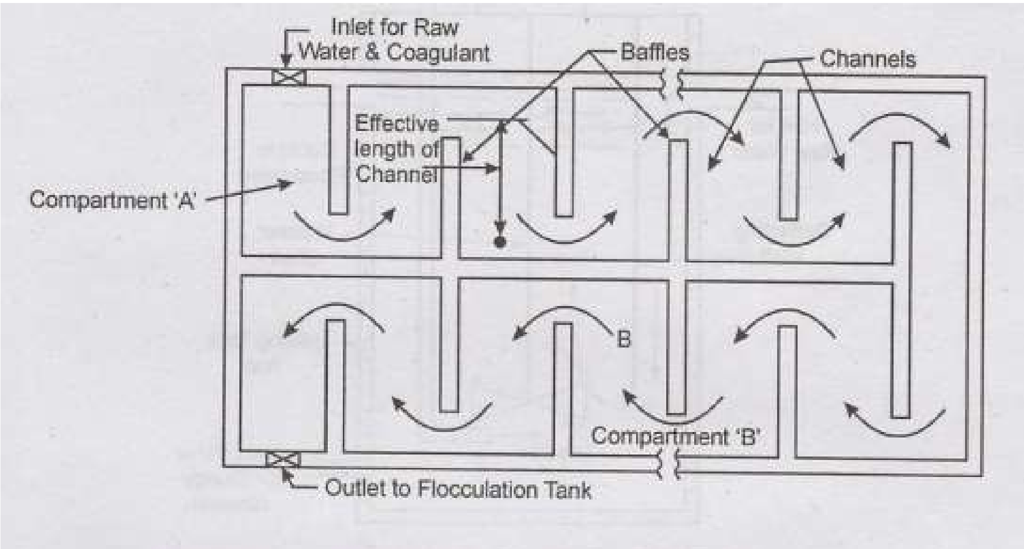


Fig. 2.9 Plan – Around the end baffle type – Horizontal flow type mixing basin

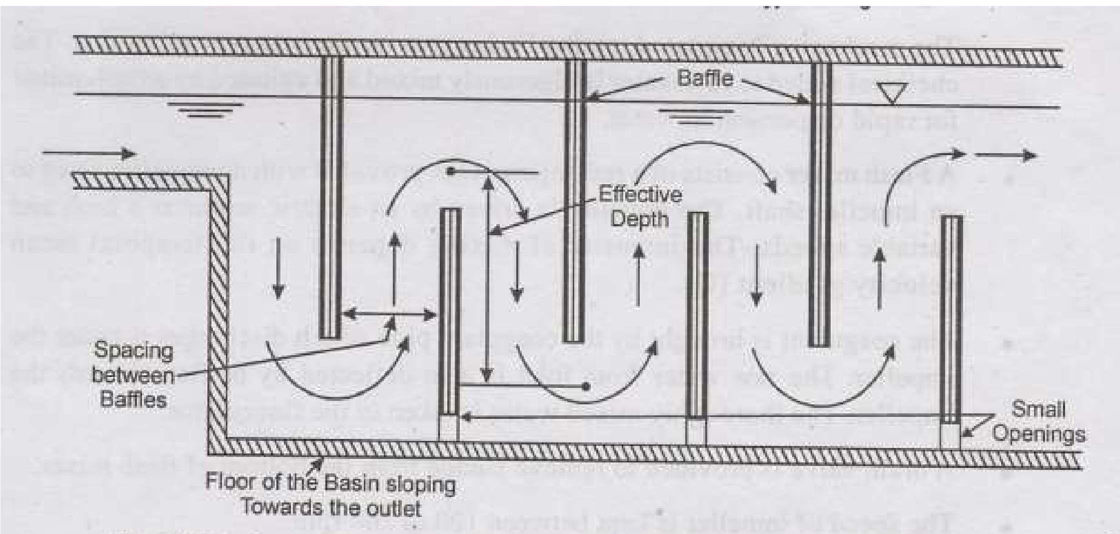


Fig. 2.10 Section of "Over and under the baffle type (Vertical flow type mixing basin)

The disturbances/ hindrances created by the baffles to the flow creates sufficient agitation and mixing The velocity of flow is controlled to a value of 0.15 to 0.45 m/s.

The detention period is 20 to 50 minutes. They are less efficient and are used only i small. WTPs. Awoll

b) Mixing basins with mechanical devices - Flash Mixer

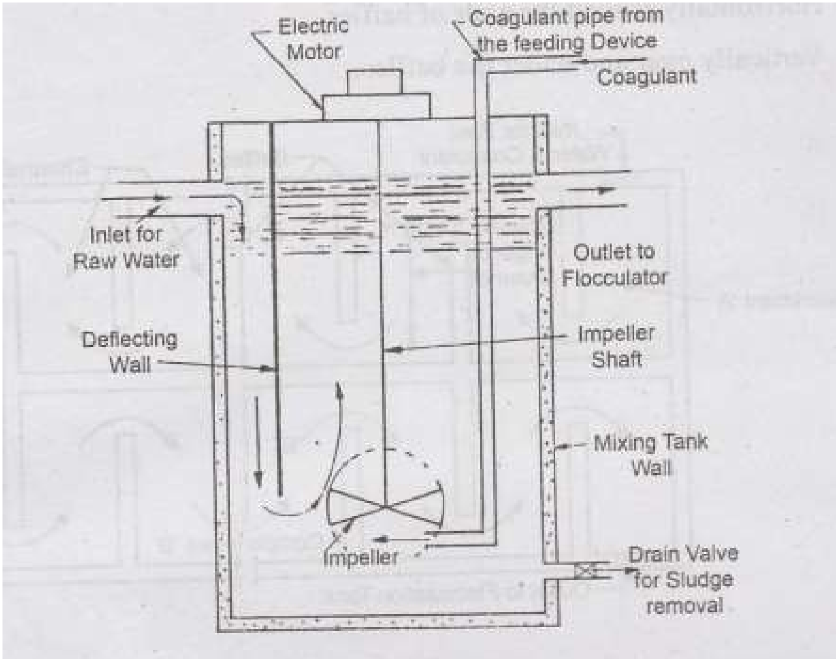


Fig. 2.11 Flash Mixer

• The mechanically agitated mixing basins provide the best type of mixing. T chemical added to raw water is vigorously mixed and agitated by a flash mix for rapid dispersion in water.

• A Flash mixer consists of a rectangular tank provided with an impeller fixed an impeller shaft. The impeller is driven by an electric motor at a high a variable speeds. The intensity of mixing depends on the temporal me velocity gradient (G).

• The coagulant is brought by the coagulant pipe which discharges it under impeller. The raw water from inlet is also deflected by baffles towards impeller. The thoroughly mixed water is taken to the flocculator.

• A drain valve is provided to remove sludge from the bottom of flash mixe

• The speed of impeller is kept between 100 to 200 rpm.

• The detention period is 1/2 to 2 minutes (30 to 60 seconds).

• The value of G is 300 s-1

• Power required is 1 to 3 Watts per m3/hr of flow.

c) Centrifugal pump

Raw water is pumped into the settling tank. Chemical is added to the suction line of

When water with coagulant passes through the impeller of pump, mixing is created.

d) Compressed air agitation

In this, raw water and coagulant are agitated vigorously by diffusing compressed air from bottom of the mixing basin.

(e) Narrow mixing channel with flume

The Coagulant is fed from the feeding tank'

The turbulance caused by vertical baffles and flumes mixes the chemical thoroughly.

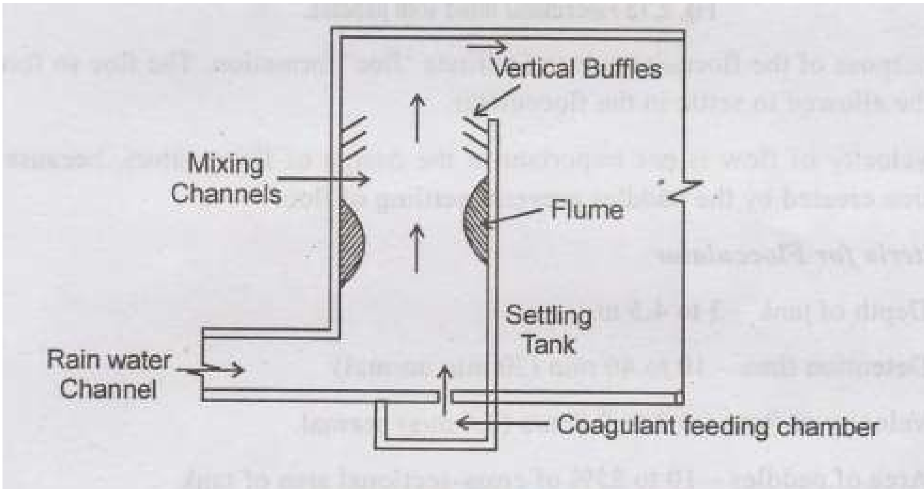


Fig. 2.12 Mixing Channel with flume

3. Flocculation Tank or Flocculator

The violent agitation in a Flash Mixer should be followed by a slow and gentle stirring to permit agglomeration of floc particles.

From the mixing basin, water is taken to the flocculator where it is given slow and gentle stirring motion.

They are rectangular tanks with paddles operated by electric motors. The water from the flocculator is taken to the sedimentation tank.

The paddles rotate at 2 to 3 rpm speed. The detention time is 20 to 60 min (30 m normally). The velocity gradient is 20 to 80 s1. The clear distance between paddles an wall or floor is 15 to 30cm.

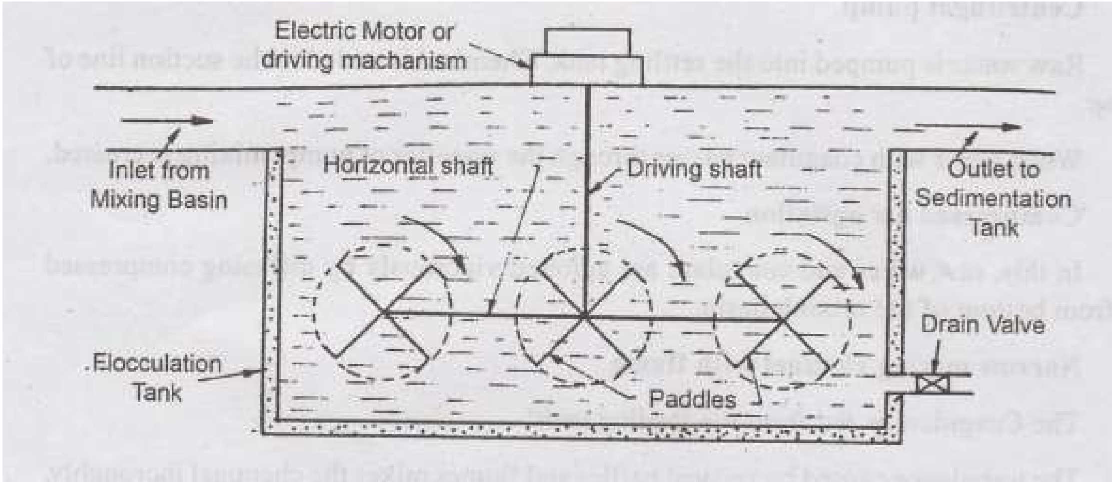


Fig. 2.13 Flocculator fitted with paddles.

The purpose of the flocculator is to facilitate 'floc' formation. The floc so forme should not be allowed to settle in the flocculator.

The velocity of flow is not important in the design of flocculators, because th rolling motion created by the paddles prevents settling of floc.

Design Criteria for Flocculator

(i) Depth of tank - 3 to 4.5 m

(ii) Detention time - 10 to 40 min (30 min normal)

(iii) Velocity of flow - 0.2 to 0.8 m/s (0.4 m/s) normal.

(iv) Area of paddles - 10 to 25% of cross-sectional area of tank.

(v) Outlet flow velocity - 0.15 to 0.25 m/s

(vi) Power consumption - 10 to 36 KW/mld.

(vii) Velocity gradient (G): 10 to 75 s-1

4. Sedimentation tank (Clarifier)

Similar to plain sedimentation tanks, except that the detention period is less (2 to 4 hrs) and has a higher surface loading (overflow) rate of 1000 to 1250 1/hr/m2 or 24 to 30 m3/d/m2 of plan area.

COMBINED COAGULATION-CUM-SEDIMENTATION TANKS

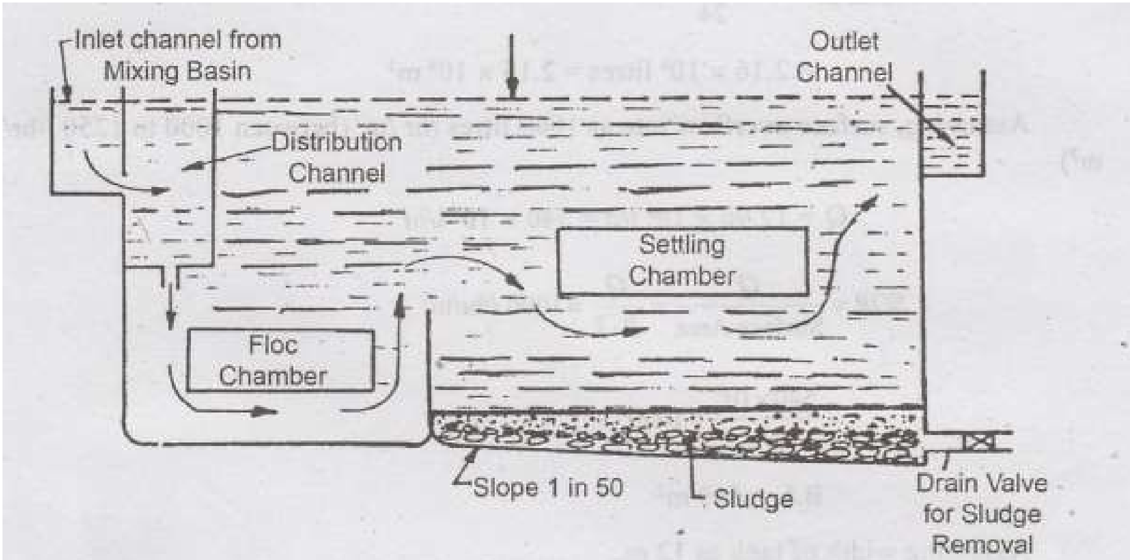


Fig. 2.14 Coagulation – Sedimentation Tank

It is a combination of coagulation and sedimentation tank. It consists of a plain floc chamber (without mechanical devices) followed by a sedimentation tank. Detention period for floc chamber is 15 to 40 minutes and for settling tank is 2 to 4 hours. The depth of floc chamber is half the depth of settling tank. The water from mixing basin enters this tank and the clarified water comes out at the outlet end. The design is similar to a sedimentation tank except that it is deeper 3 to 6 m. They are cleaned at 6 months interval.

Problem 2.2:

Design a coagulation-cum-sedimentation tank with continuous flow for a population of 60,000 persons with a daily per capita water allowance of 120 litres. Make suitable assumptions where needed.

Solution:

1. Design of Settling Tank

Average daily consumption = Population × Per capita demand

= 60,000 x 120 = 7.2 × 106 litres

Maximum daily demand = 1.8 × Average daily demand

02 = 1.8 × (7.2 × 106) = 12.96 × 106 litres

Assuming detention time of 4 hours (between 2 to 4 hours)

Capacity or Volume of Tank = Discharge x Detention Time

Volume = 12.96×106 / 24 x 4

= 2.16 x 106 litres = 2.16 x 103 m3

Assuming, surface overflow rate as 1000 litres /hr /m2 (between 1000 to 1250 l/hr/

Q = 12.96 × 106 l/d = 540 x 103 1/hr

$$SOR = \frac{Q}{\text{Surface Area}} = \frac{Q}{B \cdot L} = 1000 \ l/\text{hr/m}^2$$

$$\frac{540 \times 10^3}{B \cdot L} = 1000$$

$$\text{B.L} = 540 \text{ m}^2$$

Assuming width of tank as 12 m,

12 x L = 540 m2

L= 45 m

Volume = L x B x H = 2.16 × 103 m3

45 x 12 x H = 2.16 x 103

H = 4 m

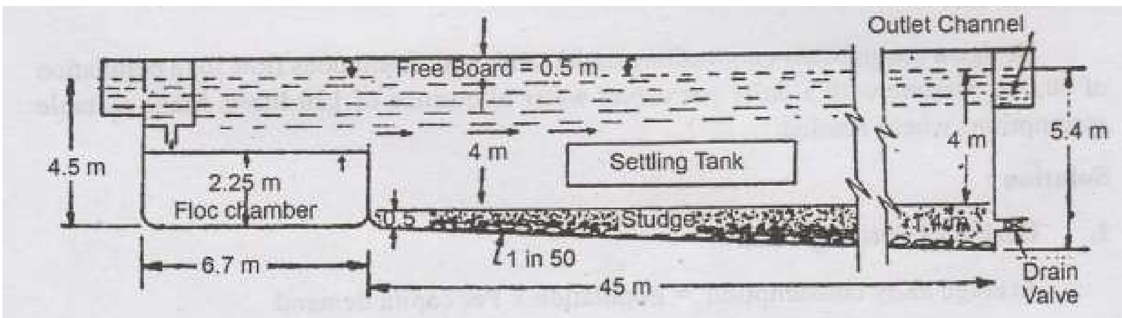


Fig. 2.15. Coagulation cum sedimentation tank

Extra depth for sludge storage (1 in 50 slope) = 45/50 = 0.9m

Assume Free Board = 0.5 m

Overall depth = water depth + sludge storage + free board

= 4 m +0.9 m + 0.5 m

= 5.4 m

Provide settling tank of dimensions 45 m x 12 m x 4m

2. Design of the Floc chamber

Depth of floc chamber = ½ x depth of settling tank

1/2 x 4.5 = 2.25 m

Assuming period of flocculation (detention period) as 20 minutes. (between 15 to 40 min)

Volume or Capacity of chamber =Q x Detention time

12.96×103 /24×60 =180m3

Area required = Volume / depth = 180/2.25 = 80m3

Using same width = 12 m,

Length of flocculation chamber = 80 /12 = 6.67 m

The dimensions of Floc chamber are = 6.

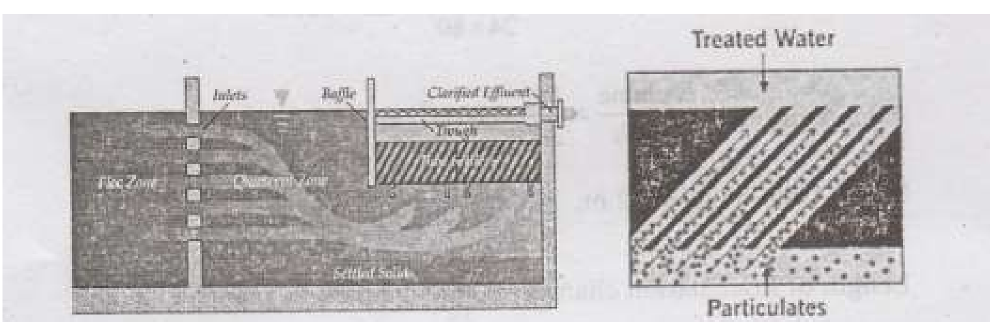
PLATE AND TUBE SETTLERS

Plate and Tube Settlers have been developed as an alternative to shallow basins and are used in conjunction with both existing and specially designed sedimentation basins. Plate and Tube Settlers are shallow settling devices consisting of stacked offset trays or bundles of small plastic tubes of various geometries. They are used to enhance the settling characteristics of sedimentation basins.

The shape, hydraulic radii, angle of inclination, and length of the plate and tube settlers will vary according to the particular installation. Normal practice is to Insert the plate or tube settlers in sedimentation basins (either rectangular or circdar) of sufficient depth. The flow within the basin passes upward through the plate or tube modules and exits from the basin above the modules. The solids that settle out within the plates or tubes move by means of gravity counter currently downward and out of the tube modules to the basin bottom.

To be self-cleaning, plate or tube settlers are usually set at an angle between 45° and 60° above the horizontal. When the angle of inclination of plate or tube is more than 60° the efficiency of the settling basin decreases. If the plates and tubes are Inclined at angles less than 45°, settler will tend to accumulate solids, which must be flushed out periodically (usually with high pressure hose). The need for flushing poses a problem with the use of plate and tube settlers where the characteristics of the solids to be removed vary from day to day.

Tube settlers are a light weight structure composed of closely spaced tubes on an incline (usually between 45° and 60°). Clarifier up flow is passed through these tubes. Settling within these tubes and contact clarification of fine floc results in a build-up of particles on the tube surfaces. Particles combine to form agglomerates which become heavy enough to slough against the upward flow and slide down the tube slope to join the sludge blanket below.



Tubes are supplied in module form - each being 1 meter wide by 1 meter long by 0.67 meters high. The modules are arranged on a supporting framework to form a layer within the clarifter. The tube settlers are suspended at a height 700mm below the top water level.

The above figure shows the supporting framework, module installation and settler positioning at Inlet clarifter in waste water treatment.

The framework is held up bv a number of ‘hooks’ over the top rim of the ciarifier tank. This was done to minimize the installation time. The entire installation may be completed in three days in an existing Water Treatment Plant, the clear water storage was filled to capacity prior to installation of the tube settlers to allow for the three days the plant was off line.

Advantages of tube settlers are:

• Solids removal efficiency will be higher leading to clarified water turbidity as less than 10 NTU

• Hence the load on the filter will be less.

• Treatment plant capacity of the existing Water treatment Plant could be increased by 50 to 60%

Advantages of Plate settlers are:

• Compact design: Space saving; Cost saving;

• No moving parts: Low maintenance; No spare parts;

• Simple installation: Saves money; Immediate start-up at full capacity

• Ease of access: Individual removal of each lamella plate; Easily available for inspection;

• Sludge handling benefits: High underflow sludge concentration; Low cost for sludge withdrawal;

• Flexible system: Retrofitting of existing tank; Custom design;

Disadvantages of Take settlers/plate settlers are

• Algae growth in tubes and platen may cause maintenance and odor problems.

• Easy to clean in Lamella but not in Tubular Module.

• Careful attention is necessary far, the design of inlet and outlet stucture to I avoid turbulence and uneven flow.

• Sometimes high pressure hose water is injected to flush out the solids.

PULSATOR CLARIFIER

The original Pulsator Clarifier was developed in the early 1950’s. Now it is a properitory item designed and installed by M/s.Degremant private Ltd.

Components of Pulsator clarifier are:

Vacuum chamber, vacuum pump and vent valve

1. Raw water distribution channel and perforated distribution pipes.

2. Lamellar Plates and/or Tubes for clarification.

3. Clarified water collection laterals and channel.

4. Sludge collection and concentrator Schematic and view of Pulsator clarifier are shown below

Working Principles of Pulsator Clarifier

• It consists of a flat-bottom tank with a series of perforated pipes at its base to distribute the raw water uniformly over the entire bottom,

• Coagulated water to pulsator flow intermittently through perforated pipes.

• Coagulant water is stored in the upper part of the vacuum chamber for a given period by creating vacuum.

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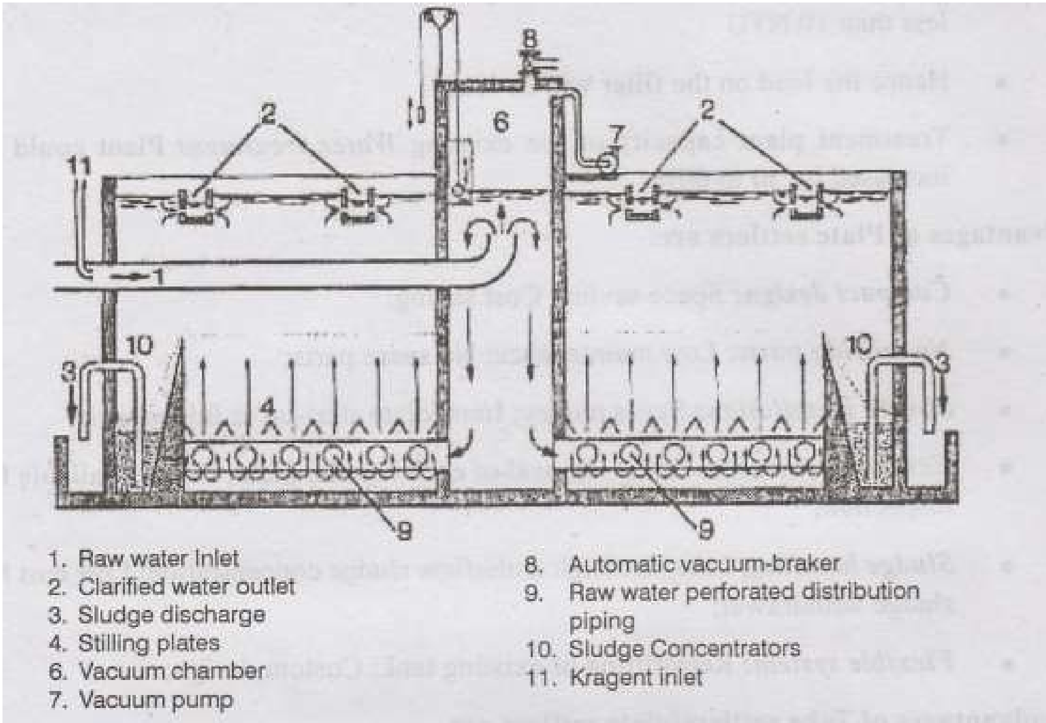

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• Coagulant water is stored in the upper part of the vacuum chamber for a given period by creating vacuum.

• The hydraulic force in then released, and the coagulated water is pulsed at a high velocity through distribution pipes into the Pulsator.

• Sludge blanket in the pulsator flocculates and remove the particles.

• A set of channels (launders) is provided at the top of the Pulsator to collect the clarified water evenly.

• By removing the air by suction from the vacuum chamber vacuum is created. As a result, the water level rises gradually inside the vacuum chamber. When it reaches a set level between 0.35 m and 0.45 m above the Pulsator water level, a contact suddenly opens an air inlet valve.

• Atmospheric pressure is immediately applied to the water stored in the vacuum chamber, which pushes the water into the perforated distribution pipes at high speed, When the water level inside the vacuum chamber reaches the low level approximately 10-20 cm above that in the Pulsator, the air inlet valve is closed and the cycle begins once again with creation of vacuum.

• The sludge blanket in the bottom part of the Pulsator is subjected to alternating vertical motions. It expands when the water rushes from vacuum chamber during drop, for a short time (5-20 sec.) and then shrinks (packs) during vacuum creation which lasts 25-50 seconds.

• Thus once in about 60 sec the water is pushed into pulsator through sludge blanke and the sludge blanket expands and shrinks once during that time.

• Frequency of pulsing is adjusted according to turbidity in raw water; For high turbidity shorter pulse interval (30 to 40 sec) and for low turbidity longer puls interval (45 to 60 sec) is provided.

• The sludge blanket gradually increases in volume due to entrapping the impuritie To contained in the feed water. When the level of the sludge blanket rises above specified level (weir level) and sludge spills into the concentrators.

• Sludge concentrator contains number of hopper bottomed tanks; The sludge i extracted from the concentrators at regular intervals.

SAND FILTRATION

The process of passing the water through the beds of granular materials (filters) known as filtration.

Purpose of filtration :

(i) To remove very fine suspended and colloidal particles that do not settle in th sedimentation process.

(ii) To remove dissolved impurities in water.

(iii) To remove pathogenic bacteria from water.on (iv) To remove colour, odour, turbidity in water.

Types of filters:

(i) Slow sand filters

(ii) Rapid sand filters

(iii) Pressure filter

Theory of filtration:

During filtration, the following actions take place:

(i) Mechanical straining

(ii) Sedimentation

(iii) Biological action

(iv) Electrolytic action

(i) Mechanical straining (for coarser particles)

When water passes through the filter media (sand), the suspended particles larger than the pore-space of the filter media get trapped and removed. The trapped particles form a mat on the filter media and help in straining more impurities.

(ii) Sedimentation (for finer particles)

The voids of the filter media acts as small sedimentation tanks and fine particles giare removed by settling.

(iii) Biological action

Certain microorganisms and bacteria present in the voids of filters form coatings over the sand grains. These organisms utilize the organic impurities in water as their food and convert them into harmless compounds by biological metabolism. They form a layer on the filter media called “schmutzdecke or dirty skin”. This layer further helps in absorbing and straining out the impurities in water

(iv) Electrolytic changes (Ionisation)

The sand grains of filter media and impurities in water are oppositely charged. When the impurities come in contact with the sand grains, their charges get neutralised and changes the characteristics of water making it purer. After certain period of time, the charge of sand grains gets exhausted and should be restored by ge of s din cleaning the filters.

Filter Media:

Sand (fine or coarse) is generally used as filter media and supported on gravel.

(i) Sand:

The properties of filter sand are :

• It should be obtained from hard and resistant quartz or quartzite.

• Free from dirt and other impurities.

• It should not loose more than 5% of its weight when placed in hydrochloric acid (HCI) for 24 hrs.

• Specific gravity = 2.55 to 2.65

• Effective size (a) 0.2 to 0.4 mm - slow sand filters.

(b) 0.35 to 0.55 mm – rapid sand filters..

• Uniformity co-efficient

(a) 1.8 to 2.5 - slow sand filters

(b) 1.3 to 1.7 - rapid sand filters

The uniformity characteristics of sand are expressed in terms of

(a) effective size (b) Uniformity coefficient.

Effective size or diameter (D10) represents a size of sieve in mm, throuth which 10% of the particles will pass i.e.,are finer than this size. Similarly, D60 size represent a size such that 60% particles are finer than it.

Uniformity coefficient (Cu) is a measure of the particle range i.e. variations in size of particles.

$$C_u = \frac{D_{60}}{D_{10}} \qquad C_u = 1 \text{ for uniformly graded sand.}$$

(ii) Anthracite - Crushed anthracite can be used as filter media separately or combined with sand (mixed media). It is costly than sand.

(iii) Garnet sand - It has high specific gravity (4.2) and is a dense material. Due to high cost, it cannot be used as a sole filter material. However, it can be used in mixed-media 30 so filter.

(iv) Other materials - Locally available materials such as shredded coconut husks, burned rice husks, crushed glass, slag, metallic ores etc. can be used as filter material.

Slow Sand Filters (SSF)

The efficiency of slow sand filters is high and they can remove larger percentage of cy of slow and filterich 000 oval base to siziano T suspended impurities and becteria. The efficiency of bacteria removal is 98 to 99%.

These filters can also remove odours and tastes caused by organic impurities (algae and plankton). They are less efficient in removing colour and can remove turbidity only upto 50mg/1.

They are not suitable for sedimented waters with high turbidity.

The rate of filtration is less (i.e. 100 to 200 litres per hour per to rapid sand filters.

They also require large area of land and are costly to install.

Their use has therefore decreased and are preferred only in smaller water treatment

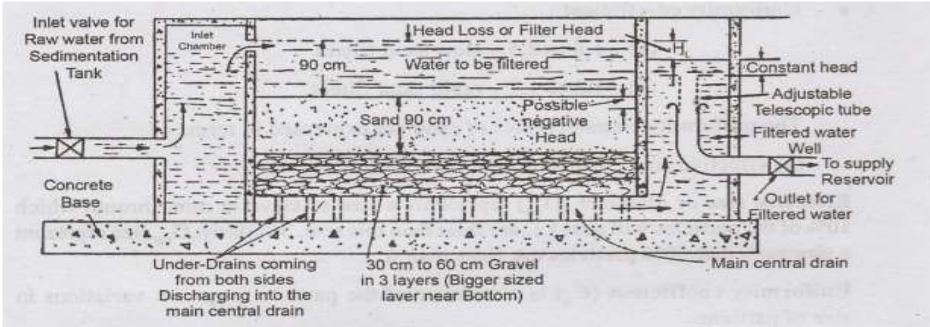


Fig. 2.16 Section of a Slow Sand Filter

Construction of Slow Sand filters

A slow sand filter consists of the following parts:

(i) Enclosure tank

It is an open basin, rectangular and built below ground level. The water-tight tank is constructed of stone/brick masonry with coating of water proof material. The floor has bed slope -1 in 100 to 1 in 200 towards the central drains. Surface area of tank varies between 50 m2 to 1000 m2. Rate of filtration is - 100 to 200 litres of water per square meter. Depth of tank varies between - 2.5 to 4 m.

(ii) Filter media

It consists of Sand layer, 90 to 110 cm thick placed over gravel.

Effective size - 0.2 to 0.35

Uniformity coefficient - 2 to 3

Sand is placed in layers of 15cm, with finer sand on the top layer and coarser sand

(iii) Base material (Gravel)

The base material is gravel, which supports the sand. It consists of 30 to 75cm thick gravels placed in three to four layers, each of 15 to 20 cm depth. The coarser gravel in the bottom layer and finest gravel in the topmost layer. The gravel size in different layers is given below:

Top 15 cm layer – Gravel size 3 to 6 mm

Intermediate layers - 6 to 20 mm / 20 to 40 mm

Bottom most 15 cm layer - Gravel size 40 to 65 mm

(iv) Under-drainage system

Filter media (sand) and base material (gravel) are laid over the under-drainage system. It consists of a central drain and lateral drains. Laterals are open jointed pipe or porous drains placed at 3 to 5m spacing on the bottom floor and sloping towards the central drain. Filtered water is collected by the laterals and discharged into the central main drain and then to the filtered water well.

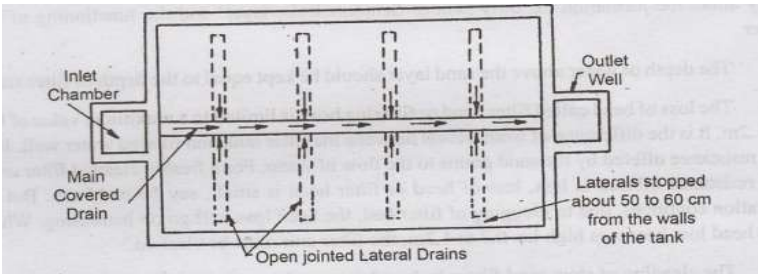


Fig. 2.17 Under drainage system (Slow sand filter)

(v) Inlet and Outlet arrangements

An inlet chamber admits water from the plain sedimentation tank and distributes over the filter media.

A filtered water well on the outlet side, collects the filtered water coming out from the main drain.

An adjustable telescopic tube in the outlet chamber maintains constant discharge through the filter.

Inlets and outlets are controlled by automatic valves.

(vi) Other appurtenances

* Vertical air pipe – is provided passing through the sand layers for proper functioning loving 192 of filtering layers. O

* Arrangements to control depth of water above sand layer (1 to 1.5m)

A meter is used to measure the flow and a gauge to measure the loss of head.

Operation and cleaning of Slow Sand Filters.

The treated water from the sedimentation tank is allowed to enter the inlet chamber of the slow sand filter and get distibuted uniformly over the filter bed. The water percolates through the filter media and gets purified during filtration. The water then enters the gravel layers and comes out as filtered water. It gets collected in the laterals (porous pipes), which discharges into the central main underdrain and finally into the ‘filtered water well’. The filtered water is then taken to storage tanks for supply and distribution. The rate of filtration is kept constant by the telescopic tube.

The water entering the slow sand filter should not be treated by coagulants, because it may affect the formation of ‘dirty skin or Schmutzdecke layer’ and the functioning of the filter.

The depth of water above the sand layer should be kept equal to the depth of filter sand.

The loss of head called filter head or filtering head is limited to a maximum value of 0.7 to 1.2m. It is the difference of water levels between the filter tank and filtered water well. It is the resistance offered by the sand grains to the flow of water. For a freshly cleaned filter unit, the resistance offered is less, loss of head or filter head is small, say 10 to 15 cm. But as filtration continues, due to clogging of filter bed, the head loss will go on increasing. When this head loss becomes high i.e. 0.7 to 1.2m, the filter unit must be cleaned.

The cleaning of slow sand filters is done by scrapping and removing the 1.5 to 3cm of top sand layer. The top surface is finally raked, roughened, cleaned and washed with good water. The amount of wash water required is 0.2 to 0.6 percent of the total water filtered. Cleaning is repeated until the sand depth is reduced to 40cm. Then new sand is added. Though the quantity of wash water required is less, cleaning involves lot of manual labour.

Slow sand filters work on the principles of mechanical straining and microbiological action. A surface coating is formed over the filter media by sticky deposits of partly decomposed organic matter. This layer is called 'Schmutzdecke' or dirty skin. This layer being sticky absorb more impurities on it which is decomposed by the micro organisms present in it. The layer increases in thickness as the filtration continues.

After 2-3 weeks of starting the operation of filters, the uppermost layer of sand will be coated with a thick film of algae, bacteria, protozoa, suspended particles and organic matter. The efficiency of the filtration process depends on the formation of 'Schmutdecke layer'. The bacteria in the layer breaks down the organic matter into simple unobjectionable compounts.

Efficiency and Performance of Slow Sand Filters

The rate of filtration is 100 to 200 litres per hour per m2 of filter area.

They are highly efficient in removing suspended solids and bacteria. The bacteria removal is 98 to 99%.

They also remove odours and tastes due to organic impurities (algae and plankton.)

• They are less efficient in removing colour of raw waters.

• They can remove turbidities only upto 50 mg/l. They are not suitable for highly 201 abnU turbid waters.

• They are suitable for small treatment plants for purifying water with low colours, low turbidities and low bacteria.

• Because of the slow rate of filtration, they require large area.

• They are costly and uneconomical for large WTPs.

Guidelines for Design of Slow Sand Filters :

The Manual on Water Supply and Treatment prepared by CPHEEO (Central Public Health and Environmental Engineering Organisation) gives the following guidelines :-

Description Recommended design value

	Description	Recommended design value
1.	Design period	10 yrs
2	Number of filter beds	
	(i) Minimum	2
	(ii) Area upto $20m^2$	2
	(iii) Area = 20 to 249 m^2	3
	(iv) Area = 250 to 649 m^2	4
	(v) Area = 650 to 1200 m^2	5
	(vi) Area = 1201 to 2000 m2	6
3	Depth of supernatant water	1m
4	Filtration rate (Normal)	0.1m/hr
5	Free board	0.2m
6	Depth of sand (filter)	
	(i) Initial	1 m
	(ii) Final (min)	0.4 m
7.	Sand Specifications	
	(i) Effective size	0.2 to 0.3mm
	(ii) Uniformity coefficient	5
8.	Gravel depth (3-4 layers)	0.3m
9	Under drains	0.2m
10	Performance standards	
	Turbidity of filtrate	1 NTU or less
	Colour of filtrate	3 or less
	Initial head loss	< 5 cm

DESIGN OF SLOW SAND FILTER

Problem 2.3:

Design six slow sand filter beds from the following data :

Population to be served	50,000 persons
Per capita demand	150 litres/ head / day
Rate of Filtration	180 litres /hr. /sq. m
Length of each bed	Twice the breadth

Assume maximum demand as 1.8 times the average daily demand.

Also assume that one unit, out of six, will be kept as stand-by.

Solution :

Average daily demand = Population × per capita demand

= 50,000 × 150 litres / day

Maximum daily demand = 1.8 × Average daily demand

$= 1.8 \times 7.5 \times 10^6 = 13.5 \times 10^6$ litres/ day

Rate of filtraton = 180 litres/hr/sq.m = (180 × 24) litres/d/sq.m

Total surface area of filters required

$$= \frac{\text{Max.daily demand}}{\text{Rate of filtration per day}}$$

$$= \frac{13.5 \times 10^6}{180 \times 24}\ \text{sqm} = 3125\ m^2$$

6 units are used with 1 unit as standby, Hence consider only 5 units for filtration

$$\text{Area of each filter unit} = \frac{3125}{5} = 625\ m^2$$

Area = 625 m^2

$L \times B = 625$

$\because L = 2B$

$(2B)\ B = 625$

$B^2 = 312.5$

$B = 17.7 \simeq 18$ m

Now, $L = 2B = 2 \times 18 = 36$ m

Hence, use 6 filter units with one unit as standby, each unit of size 36 m x 18 m, arranged in series with 3 units on either side.

Rapid Sand Filter

Rapid Sand Filter: Gravity Type

Rapid sand filters are of two types:

(i) Gravity type - It uses larger and coarser sand as filter media to increase the rate of filtration.

(ii) Pressure type - Water is filtered under pressure, thereby increasing the rate of filtration.

A gravity type rapid sand filter consists of the following parts:

1. Enclosure Tank:- It is smaller in size, generally rectangular in shape, constructed 3.5m. Surface area of each unit is 20 to 50 m2 and are arranged in series. The L/B ratio is 1.25 to 1.35. RCC or CI troughs are provided in the tank to distribute water during operation and for collection of wash water during cleaning (backwashing) m.pables

2. Filter Media (Sand) : Sand should be free from dirt, organic and suspended matters Hard and resistant preferably quartzite; depth of sand 0.6 to 0.9m; Effective size 0.35 to 0.6mm; Uniformity coefficient 1.2 to 1.7. Due to increased effective size and decreased uniformity coefficient, the void space is more which increases the rat of filtration.

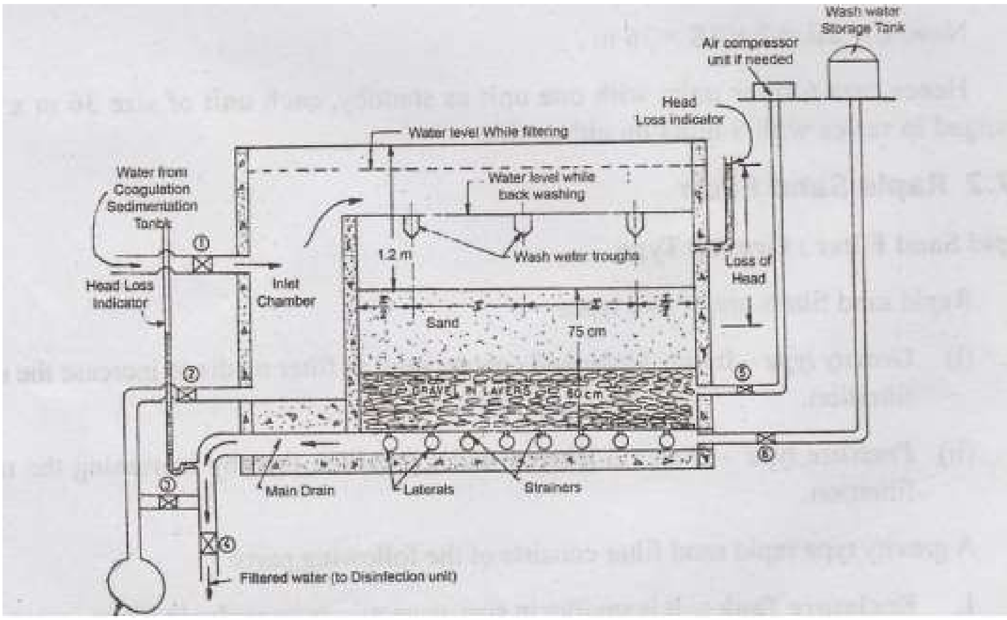
3. Base Material (Gravel): The sand media is supported on graded gravel layers Gravel should be free from clay, dirt and organic matter and should be hard, durabl not and round. Its depth is 45 to 60 cm and normally laid in layers:

Layer	Depth	Grade size
Top most	15 cm	2 mm to 6 mm
Intermediate	15 cm	6 mm to 12 mm
Intermediate	15 cm	12 mm to 20 mm
Bottom most	15 cm	20 mm to 50 mm

4. Underdrainage system: It serves two purposes

(i) Collects the filtered water

(ii) Distribute wash water uniformly upward during cleaning (backwashing)



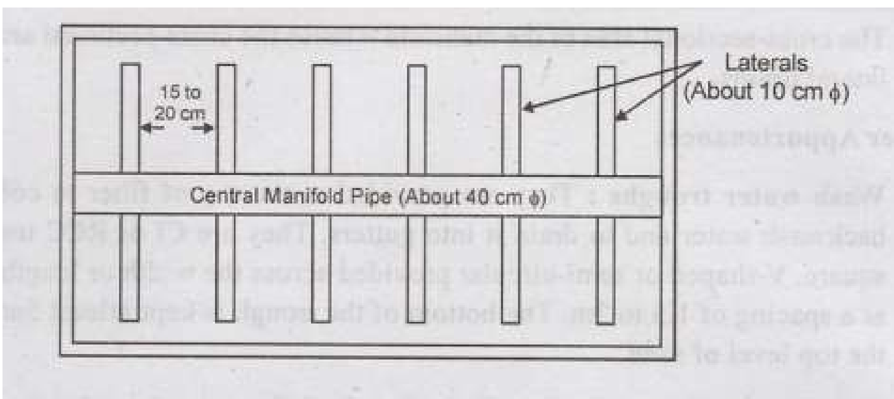


Fig. 2.19 Under drainage system for a rapid (gravity) sand filter

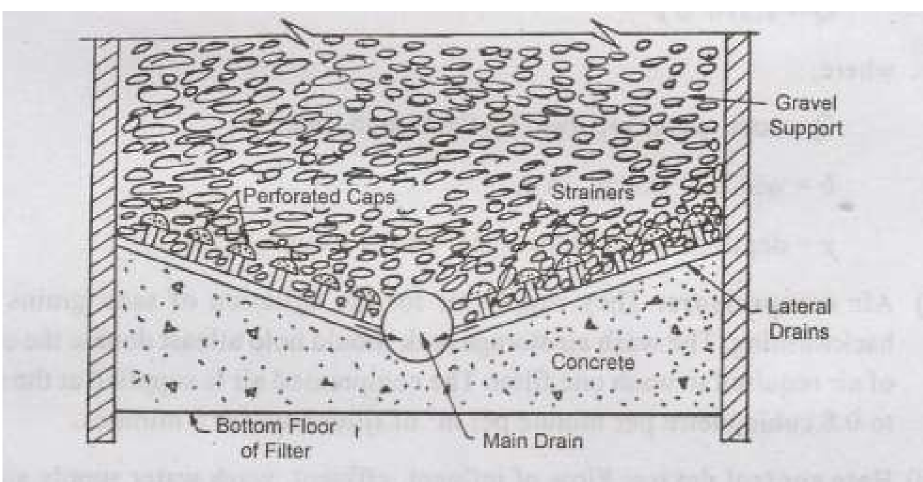


Fig. 2.20 (Section) Under drainage system for a rapid (gravity) sand filter

The under drainage system consists of manifold and laterals. The manifold is a 40cm diameter pipe running lengthwise at the centre of the floor bottom. Laterals are 10 cm dia pipes that take off from the manifold in both direction at right angles at 15 to 30 cm spacing. There are two types of manifold and lateral systems:

(i) Perforated pipe type: In this, the lateral drains are provided with holes at bottom side.

(ii) Pipe and Strainer type: In this, strainess are placed on laterals. A strainer is a small brass pipe closed at its top by a perforated cap.

The following rules are followed in the design of under drainage system :

a) The total cross-sectional area of perforations = 0.2 percent of total filter area.

(b) The cross-sectional area of each lateral = 2 to 4 times total cross-sectional

(c) The cross-sectional area of the manifold = twice the cross-sectional area of the lateral drains.

5. Other Appurtenances

(i) Wash water troughs: They are provided at the top of filter to collect the backwash water and to drain it into gutters. They are CI or RCC troughs of square, V-shaped or semi-circular provided across the width or length of tank at a spacing of 1.5 to 2m. The bottom of the trough is kept atleast 5cm above the top level of sand.

Size of the trough can be found by using the following expression:

Q = 1.376 by3/2

where,

Q = total water received by the trough, in m3/s

b = width of trough, in m

y = depth of water at the upper end of trough, in m.

(ii) Air compressors: They supply air for the agitation of sand grains during backwashing. The wash air storage tank should hold atleast double the capacity of air required to wash one filter. The compressed air is supplied at the rate 0.6 to 0.8 cubic metre per minute per m2 of filter area for 5 minutes.

(iii) Rate control device: Flow of influent, effluent, wash water supply and wash water waste must be controlled. A constant rate of filtration is maintained irrespective of the head loss by using rate controllers (venturi type). Otherwise sudden change in the rate of filtration could damage the sand filter bed.

Working and washing of Rapid Sand Filters :

The working of rapid sand filter is controlled by 6 valves:

Valve A : Inlet/ Influent valve through which water from coagulation- clarification basin enters the filter unit.

Valve B: Filtered water storage tank valve.

Valve C: Waste water valve to drain water from main drain.

Valve D: Waste water valve to drain water from inlet chambers

Valve E: Wash water storage tank valve

(i) During Normal Working condition:

All valves are closed except A and B, which are kept opened.

Valve A: To permit water from coagulation-sedimenation basin to inlet chamber.

Valve B: To carry filtered water to filtered water storage tank. 2 m head of water is maintained above the sand bed.

Filtration rate is 3000 to 6000 litres/hr/m2 of filter area

(ii) During Backwashing :

The Loss of head initially in a clean filter bed is usually 15 to 30 cm.

As filtration continues, impurities are trapped in the filter media and it provides greater resistance to the flow of water, due to which the head loss goes on increasing.

The permissible head loss in rapid sand filter is 2.5 to 3.5m.

When head loss increases beyond permissible value, the filter bed requires cleaning, which is done between 2 to 4 days interval.

During backwashing, high velocity air and water is made to flow upwards either in combination or first compressed air followed by wash water.

The following sequence of operations is followed :

Close influent Valve A - Allow the filter to operate till the water level falls to the edge of troughs or 15 cm from top of sand.

Close effluent valve B. Open air valve F - Air is blown at a rate of 1 to 1.5 m3 of air/min/ m2 of filter area for 2 to 3 minutes which loosens the scum/ dirt.

Close air valve F.

Open wash water valve E - and waste water valve D-Wash water jets flow upwards (and the waste water from backwashing is drained into

Cleaning is continued till the wash appears clear.

Close wash water valve E. Close waste water valve D.

Allow the solids to settle and form sticky layer on filter media.

Open valve C leading filtered water to wash water drain for few minutes.

Close valve C.

Open valve B - Normal filtration operation is continued.

- The permissible filter bed expansion during backwashing is 25 to 50% of its depth.

• Rate of application of wash water is 600 litres per sq. m. of filter area.

The rapid sand filters get clogged very frequently and have to be washed every 24 to 48 hours. Normally 10 to 30 minutes is required for backwashing.

DESIGN OF RAPID SAND FILTERS

Problem 2.4:

Design a set of rapid gravity filters for treating water required for a population of 50,000; the rate of supply being 180 litres per day per person. The filters are rated to work 5000 litres per hour per sq.m. Assume whatever data are necessary.

Solution:

Hence, two units of size 10 m x 6.75 m are provided with one additional unit as stand-by.

Problem 2.5:

Design a rapid sand filter for 4 MLD of supply with all its principal components.

Solution:

Average demand = Population × per capita demand

$= 50{,}000 \times 180 = 9 \times 10^6$ l/d

Maximum demand = 1.8 × Avg. daily demand

$= 1.8 \times 9 \times 10^6$ l/d

$= 16.2 \times 10^6$ l/d

Water demand per hour $= \dfrac{16 \cdot 2 \times 10^6}{24}$ l/hr

$= 0.675 \times 10^6$ l/hr

Rate of filtration = 5000 l/hr /sq.m. (given)

$$\text{Area of filter beds required} = \frac{\text{Water demand}}{\text{Rate of filtration}} = \frac{0.675 \times 10^6}{5{,}000} \; \frac{l/hr}{l/hr/m^2}$$

$= 135\ m^2$

Since two units are designed,

Area of each uni: $= \dfrac{135}{2} = 67.5 m^2$

Assuming $\dfrac{L}{B} = 1.5$

$L \times B = 67.5$

$(1.5B)\, B = 67.5$

$B = 6.75$m.

$L = 1.5 \times 6.75$

$= 10$m

Water required per day = 4 million litres

Assuming 4% of filtered water is used for backwashing

Total filtered water required per day

= 1.04 x 4 ML = 4.16 MLD

Assuming 0.5 hr (30 min) is lost in backwashing everyday

Filtered water required per hour = 4.16/23.5ML/hr (operation time is 23.5 hours)

= 0.177 ML/hr

Assuming rate of filtration = 5000 l/hr/sq.m.

0.177×106

Area of filter required = 0.177 x 106/5000

1/hr / 1/hr/m2 = 35.4m2

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Assuming that 2 units are provided

Area of each unit =35.4./ 17.7m2

Assuming = L/B =1.5

Area = L x B = 17.7 m2

(1.5B)B = 17.7

B = 3.43 m/L = 1.5 x 3.43 = 5.14m

Hence, adopt 2 filter units with dimensions

5.2 m x 3.4m

Design of under-drainage system (Manifold and Lateral system)

Total area of perforations = 0.2% of total filter area

(assuming 13 mm dia)

= 0.2 /100 x (5.2×3.4)

= 0.035 m2

Total area of laterals = 2 x total area of perforations

= 2 x 0.035 = 0.070 m2

Area of manifold = 2 x area of laterals

= 2 x 0.07 = 0.14 m2

Diameter of manifold (circular pipe) π/4 I d2 = 0.14 m2

$$d = \sqrt{\frac{0.14 \times 4}{\pi}} = 0.42m$$

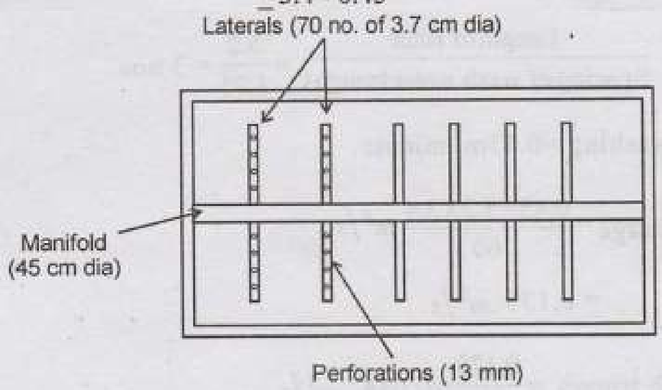
Use 45 cm dia manifold pipe laid lengthwise along the centre of filter bottom. Laterals are laid perpendicular to manifold width-wise at spacing of 15 cm.

No. of laterals $= \dfrac{\text{Length of filter}}{\text{spacing of laterals}} = \dfrac{5 \cdot 2\text{m} \times 100}{15\text{cm}} = 34.6 \text{ (say 35)}$

35 laterals on either side, hence total 70 laterals.

Lateral length $= \dfrac{\text{Width-Manifold diameter}}{2}$

$= 3.4 - 0.45$



Under drainage system

Adopt 13 mm perforations in laterals

Total area of perforation $= 0.035 \text{ m}^2 = 350 \text{ cm}^2$

$$N \times \frac{\pi}{4}(1.3)^2 = 350$$

where N = total number of perforation in all the 70 laterals

$$N = \frac{350 \times 4}{\pi \times (1.3)^2} = 264$$

No. of perforations in each lateral

$$= \frac{264}{70} = 3.8 \text{ say } 4$$

Area of perforations per lateral

$$= 4 \times \frac{\pi}{4} \times (1.3)^2 = 5.3\text{cm}^2$$

Area of each lateral = 2 × Area of perforations

$$= 2 \times 5.3 = 10.6 \text{ cm}^2$$

Dia of each lateral $= \sqrt{10.6 \times \dfrac{4}{\pi}} = 3.7\text{cm}$

Hence, Use 70 laterals each of 3.7 cm dia at 15 cm c/c, each having 4 perforations of 13mm size, with 45 cm dia manifold.

$$\text{No. of troughs} = \frac{\text{Length of filter}}{\text{Spacing of wash water troughs}} = \frac{5.2}{1.75} = 3 \text{ nos}$$

Assume rate of washing =0.45m/ minute.

$$\text{Wash water discharge} = \frac{0.45 \times 5.2 \times 3.4}{60} \; m^3/s$$

$$= 0.133 \; m^3/s$$

$$\text{Discharge in each trough} = \frac{0.133}{3} = 0.044 \; m^3/s$$

$Q = 1.376.\ b.\ y^{3/2}$

Q = discharge m^3/s

b = width = 0.2m (assumed)

y = depth in m

$0.044 = 1.376 \times 0.2 \times y^{3/2}$

$$y^{3/2} = \frac{0.044}{1.376 \times 0.2} = 0.16$$

y =0.3 m = 30cm

Keeping 5 cm free board, adopt depth of trough = 30 + 5 = 35cm

Table 2.1: Comparison between Slow and Rapid Sand Filters

Sl. No.	Item	Slow Sand Filter	Rapid Sand Filter
1	Rate of filtration	100 to 200 litres per hour per m^2	3000 to 6000 litres per hour per m^2
2	Size of bed	Requires large area	Requires small area
3	Coagulation	Not required	Essential
4	Filter media or sand	Effective size :0.2 to 0.35 mm Uniformity coefficient:2 to 3, Depth : 105 cm	Effective size : 0.35 to 0.6 mm Uniformity coefficient : 1.2 to to 1.7, Depth : 75 cm
5	Base material or gravel	Size : 3 to 65 mm Depth : 30 to 75 cm	Size : 3 to 40 mm Depth : 60 to 90 cm
6	Underdrainage system	Perforated pipe laterals discharging into main drain	Perforated laterals with mains or wheeler system or Leopald or Wagner system
7	Method of cleaning	Scrapping of top layer to 15 mm to 25 mm	Backwashing with or without compressed air
8	Period of cleaning	1 to 2 months	2 to 3 days
9	Efficiency	Very efficient in bacteria removal but less efficient in removal of colour and turbidity	Less efficient in bacteria removal, more efficient in removal of colour and turbidity
10	Economy	High initial cost	Cheap and economical
11	Flexibility	Not flexible in meeting variations in demand	Quite flexible for reasonable variations in demand
12	Skilled supervision	Not essential	Essential

DISINFECTION

The filtered water from the Slow or Rapid sand filters normally contains some harmful pathogenic (disease causing) bacteria. These bacteria must be killed in order to make the water safe for drinking. The process of killing these harmful bacteria is called disinfection and the chemicals used in this process are called disinfectants. Disinfection not only kills the bacteria during treatment but also prevents any recontamination during the distribution of water to the consumer. The disinfectant chemicals used should therefore be able to give residual sterilizing effect for a long period.

Minor Methods of Disinfection

1. Boiling of water (Sterilization): Most effective method since boiling of water kills all the bacteria and micro-organisms. However, this method is not feasible for large scale public water supplies. During epidemics, the consumers are advised to boil the water before drinking.

2. Treatment with excess lime: Excess lime added increases the pH of water to greater than 9.5, when E-coli present in water will die. The bacterial removal efficiency is upto 99 to 100%. However, the excess lime added has to be removed by re-carbonation or other suitable methods, before supplying it to the consumers. The dosage of lime is between 10 to 20 ppm of Calcium Oxide.

3. Treatment with ozone: Ozone gas is faintly blue gas of pungent odour and is

$$3O_2 \longrightarrow 2O_3 \longrightarrow O_2 + O$$

Because of its instability, ozone readily breaks down into oxygen and nascent oxygen (O). The nascent oxygen is a powerful oxidizing agent and removes the bacteria as well as organic matter from water. The dosage is 2 to 3 ppm and contact period is 10 minutes. In addition, Ozone removes the colour, taste and odour from water. However, it is very costly.

4. Treatment with iodine and bromine: Addition of iodine and bromine to water kills the pathogenic bacteria. The dosage is 8 ppm and contact period is 5 minutes. They are not used for treating large scale public supplies, but may be used for small water supplies for army troops, private plants, swimming pools Is etc.

5. Treatment with ultra-violet rays: UV rays are effective in killing both the active bacteria as well as spores. Though Sun is a powerful source of UV rays, it requires large exposure area and long time. Hence UV rays are generated by mercury vapour lamps enclosed in a quartz globe. Water should be made to flow in thin films over the lamp and it should be colourless with turbidity less than 15 ppm. This method is costly and hence not commonly used except in private buildings, office buildings, institutions and swimming pools.

6. Treatment with potassium permanganate: Common method in rural areas. Potassium permanganate (KMnO,) is dissolved in a bucket of water and is mixed with the well water. The dosage is 1 to 2 mg/L with contact period of 4 to 6 hours. Addition of potassium permanganate imparts pink colour to water and the water should not be used during the first 48 hours.

7. Treatment with silver, called Electro-Katadyn process: Silver when immersed in water exerts an inhibiting action on bacterial life. Silver ions, with or without activators (palladium

or gold) are deposited on particles of granular activated carbon. Bacteria laden water contacting the silver impregnated carbon release minute quantities of silver - 25 to 40 ppb which acts as a disinfectant. The contact time varies from 10 to 60 minutes. Since silver is costly, this method is suitable for small installations or for private individual houses.

Chlorination

Chlorine is universally adopted for disinfecting public water supplies. It is cheap, reliable, easy to handle, easily measurable and capable of providing residual disinfecting effects for long periods, thus affording complete protection against future recontamination of water in the distribution system. The only disadvantage is that when used in excess, it When chlorine is added to water, it forms hypochlorous acid or hypochlorite ions, which have immediate disastrous effect on microorganisms.

$Cl_2 + H_2O \rightarrow$ HOCI (hypochlorous acid) + HCI

HOCI$\rightarrow$ H^+ (hydrogen ion) + OCH (Hypochlorite ions)

The hypochlorous acid is unstable and may break into hydrogen ions and hypochlorite ions. The above reaction is reversible and depends on pH of water. The sum of hypochlorous acid, hypochlorite ions, and molecular chlorine existing in water is called free available chlorine. Out of these, hypochlorous acid (HOCI) is more destructive and the pH of water is maintained slightly less than 7, so as to control the dissociation of HOCI.

Moreover, the chlorine will immediately react with ammonia present in water to form chloramines,

$$NH_3 + HOCl \rightarrow NH_2Cl \text{ (Monochloramine) } + H_20$$
$$NH_2Cl + HOCl \rightarrow NHCl_2 \text{ (Di-chloramine) } + H_20$$
$$NHCl_2 + HOCl \rightarrow NCl_3 \text{ (Nitrogen Trichloramine) } + H_20$$

The chloramines formed are stable and are found to possess disinfecting properties. When the added chlorine has consumed all the ammonia available in water, then it will persist as free chlorine. The combination of chlorine with ammonia in the form of chloramines is called the Combined Chlorine, and is less effective in causing disinfection compared to free chlorine.

The free chlorine as well as the combined chlorine (chloramines) will cause germicidal action on bacteria and pathogens. The free chlorine will instantaneously kill the pathogens, while the combined chlorine will provide long term germicidal effect.

In general, most of the waters are satisfactorily disinfected if the free chlorine residual is about 0.2 mg/l, 10 minutes after the chlorine is applied.

Various forms in which chlorine can be applied:

- Liquid chlorine or chlorine gas
- Hypochlorites or bleaching powder
- Chlorine tablets
- Chloramines ie., mixture of ammonia and chlorine

• Chlorine dioxide

(i) Bleaching powder: Bleaching powder or calcium hypochlorite Ca(OCI), is a chlorinated lime containing about 33% of available chlorine. It loses its strength during storage or exposure of air. It is therefore used only on small installations or under emergency conditions.

$$Ca(OCl)_2 + {}_2H_20 \rightarrow 2HOCl + Ca(OH)_2$$

$$NaOCl \text{ (sodium hypochlorite)} + H_20 \rightarrow HOCl + NaOH$$

The process of chlorination with hypochlorites is known as hypochlorination. ovito Commerical compounds such as HTH (high test hypochlorites), Pittclor, Pittcide, no Hoodchlor etc are used instead of bleaching powder. The HTH has chlorine content of 65 to 70%. Hypochlorites are applied to water as a solution by means of hypochlorite feeding apparatus. It consists of a solution tank connected to a constant level feeding tank. The dosage of the solution is adjusted by means of an adjustable pinch clamp.

(ii) Chloramines: Chloramines, the combination of ammonia and chlorine are widely used as they produce a more stable disinfecting residual than produced by chlorine alone. In this treatment, ammonia is added to water just before the chlorine is applied. The usual proportions are 1 part of ammonia to 4.5 parts of chlorine by weight. Ammonia may be used in the form of gas or liquid or ammonium sulphate or ammonium chloride. Since the disinfecting action of chloramines is slower than chlorine alone, a contact period of 2 hours should be provided before the water is used.

(iii) Free Chlorine: Chlorine is generally applied in gaseous form or in liquid form. Gaseous chlorine is a greenish-yellow poisonous substance, with a typical odour and is 2.48 times heavier than air. Liquid chlorine is amber coloured oily liquid and about 1.44 times heavier than water. Unconfined liquid chlorine rapidly onino vapourises to gas, 1 volume of liquid yields 462 volumes of gas. Chlorine is stored and supplied in liquid form in metal containers under pressure. Since liquid chlorine is highly corrosive, the cylinders containing liquid chlorine are provided with special fittings. Chlorine gas is a respiratory irritant and it can cause varying degrees of irritation to skin, mucous membranes and respiratory system. Chlorine cylinders should be stored in a cool well-ventilated room. The chlorine dose depends upon : Organic matter present in water, pH of water, amount of carbon dioxide present in water, temperature and time of contact.

(iv) Chlorine Dioxide: Bactericidal properties of chlorine dioxide is greater than chlorine. The chlorine dioxide gas is unstable, and is therefore produced at the

It is harmless in aqueous solution. It does not react with organic materials to produce any harmful substances. It has greater oxidizing ability than chlorine. The dosage varies from 0.5 to 1.5 ppm and is not affected by variations in pH. However due to its high cost of production, it is rarely used.

$$2NaClO_2 + Cl_2 \rightarrow 2NaCl + 2ClO_2$$

Forms of Chlorination

Depending upon the stage at which chlorine is applied to water, chlorination may be of the following forms:

(i) Plain chlorination: The application of chlorine to raw or untreated water supply as it enters the distribution system. It also includes the chlorination of raw waters in tanks or reservoirs to check the growth of weeds, organic matter, algae and bacteria. It also removes colour and odour from water. This is done when water is relatively clear with turbidities less than 20 to 30 ppm. The normal dose is between 0.5 to 1 ppm.

(ii) Pre-chlorination: It is the application of chlorine to water before its treatment yllups (filtration or sedimentation). This helps in reducing the amount of coagulants required because of the oxidation of organic matter by chlorine. The dosage of chlorine is adjusted such that the chlorine residual is 0.1 to 0.5 ppm.

Advantages of pre-chlorination:

• It reduces the quantity of coagulants required

• It reduces the bacterial load on filters

• It controls algae and plankton growth in basins and filters

• It eliminates tastes and odours

(iii) Post-chlorination: It is the application of chlorine in water after its treatment. This is the standard procedure followed in which chlorine is added to water as it leaves the rapid sand filters and before it enters the distribution system. The dose of the chlorine should be so adjusted that the residual chlorine is about 0.1 to 0.2 ppm. It is useful for protection against recontamination during distribution.

(iv) Double or multiple chlorination: It refers to the application of chlorine at two or more points in the purification process. Generally, double chlorination is resorted to, in which chlorine is applied just before water enters the sedimentation tanks, and after it leaves the filter plants. This is done specially when raw water is highly The advantages of double chlorination are similar to those of pre-chlorination with greater factor of safety against pathogenic microorganisms.

(v) Break Point Chlorination: When chlorine is applied to water, two actions take place one after the other:

• Chlorine acts as disinfectant and kills bacteria.

• Chlorine acts as oxidizing agent and it oxidizes the organic matter.

Chlorine Demand: Chlorine compounds are good oxidizing agents and hence they react with organic and inorganic impurities present in water, before the disinfection is achieved. The amount of chlorine consumed in the oxidation of these impurities is known as chlorine demand of water. Only after the chlorine demand of water is fulfilled, the chlorine will appear as free available chlorine to kill the pathogenic microorganisms. Chlorine demand is therefore, the difference between the amount of chlorine added to water and the quantity of free available chlorine remaining at the end of the specified contact period.

Break point chlorination is a term which gives us an idea of the extent of chlorine to be added to the water. In fact, it represents, that much dose of chlorination, beyond which any further addition of chlorine will equally appear as free residual chlorine.

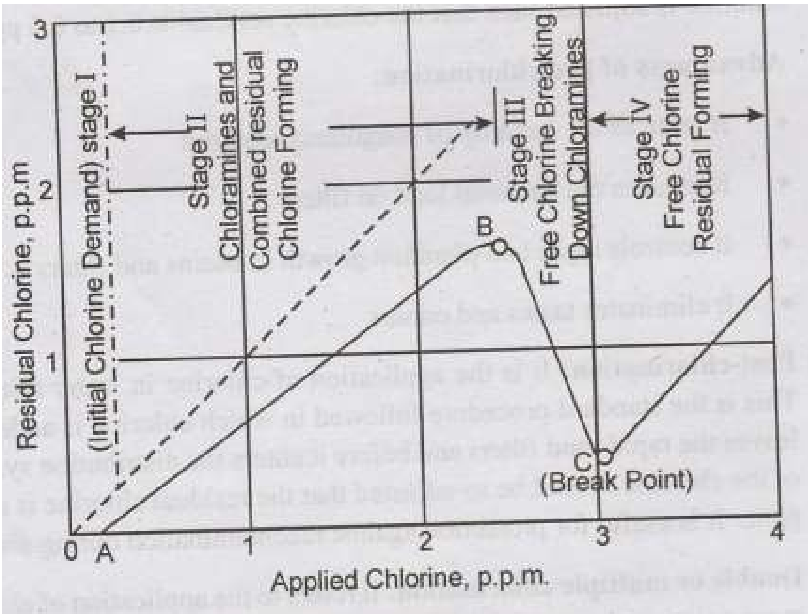


Fig. 2.21 : Break point chlorination

When chlorine is added to pure water which has no organic impurities But, water generally has some impurities or chlorine demand and as such results in curve ABC, shown in figure 2.21. When chlorine is added to the water, it first reacts with the ammonia present in the water, so as to form chloramines. The residual chlorine curve (AB) therefore increases with the applied chlorine dosage but shall be slightly less than the applied chlorine as some chlorine is consumed for killing the bacteria. If the addition of chlorine is continued abizorby beyond the point B, chlorine oxidizes the organic impurities in water and therefore, the residual chlorine curve falls down, (BC). This point "C" is called the break point, as any chlorine that is added to water beyond this point, breaks through the water and totally appears as residual chlorine. The addition of chlorine beyond break point is called break point chlorination.

General practice is to add chlorine beyond the break point and ensure a residual of 0.2 to 0.3 mg/l of free chlorine.

(vi) Super chlorination: Super-chlorination is the application of excessive amount of chlorine (5 to 15 mg/l) to the water to give about 1 to 2 mg/l of residue beyond the break point. This may be required in some special cases of highly polluted waters containing high concentration of organic impurities, or during pinsgro di epidemics of water borne diseases or when water contains cysts of E. histolytica (organism causing amoebic dysentery). Sometimes, even higher doses may be used and the resultant water is dechlorinated before distribution.

(vii) Dechlorination: It is the process of removing excess chlorine from water before noision distribution to the consumers to avoid chlorine tastes. It should be done in such a way that some residual chlorine remains in water. Dechlorination is achieved either by aeration or by the use of chemicals such as sodium thio- sulphate, sodium bio-sulphate, sodium sulphite, activated carbon, potassium permanganate or sulphur dioxide in gas or liquid form. Sulphur dioxide and sodium disulphite are preferred for large supplies. Sodium dioxide gas is applied in the same manner as the chlorine gas with contact period of 10 minutes and dosage of 0.3 to 0.6 ppm. Super-chlorinated water may also be filtered through beds of granular activated carbon, when excess chlorine oxidizes carbon to carbon dioxide due to which odour, taste and colour are removed.

SOFTENING - REMOVAL OF IRON & MANGANESE

• Iron and Manganese salts are generally found together in well water or anaerobic reservoir waters, in invisible dissolved state.

• When exposed to air, these reduced forms slowly transform to insoluble visible oxidized ferric iron and manganic manganese.

• The reddish tinge in water is due to the presence of iron and brownish tinge due to manganese. When their concentration exceed 0.3mg/l, they becom objectionable due to the following reasons:

(i) Cause discolouration of clothes- due to deposition of red/brown coloure oxides of iron/manganese.

(ii) Cause incrustation of water pipes- due to deposition of ferric hydroxi and manganese oxide.

Remedy: Periodic flushing of small distribution pipes may be effecti in removing accumulation of rust particles.

(iii) Cause unpleasant taste and odour.

(iv) Cause troubles in various manufacturing processes.

(v) Promotes growth of bacteria (Crenothrix) in water mains. Elimination iron bacteria is difficult and expensive.

(vi) Sulphate iron cause acidity and corrosive action on iron and brass.

The iron and manganese may be present in water either in combination with organ matter or without such combination and the treatment differs accordingly:-

1. Iron and Manganese without combination with organic matter.

• They can be easily removed by aeration followed by coagulation, sedimentati anf filtration.

Aeration → coagulation → sedimentation → filtration

• The different methods of aeration/ aerators adopted are: oib tunglue

(a) Cascade aerators

(b) Spray nozzles

(c) Trickling beds

(d) Diffused aeration

Note: The different types of aerators are discussed in the previous section.

• By aeration, the soluble ferrous and mangenese compounds present in wat are oxidized into insoluable ferric and manganic compounds, which can sedimented out easily.

• The precipitated floc can be made to settle down in settling tanks or be furth removed in gravity or pressure filters.

The following reaction takes place :

$4Fe + 0_2 + 10\ H_2O = 4Fe(OH)_3\downarrow + 8H$

1mg of Fe requires 0.14mg of O_2.

A reaction period of about 5 minutes or less, at a pH of 7 to 7.5, and 0.14mg of oxygen is required to convert 1mg of ferric iron to ferric hydroxide.

The amount of oxygen required for the oxidation of ferrous iron is only about 0.14 part per part of iron, so that slight agitation with air is sufficient.

When iron is present as ferrous bicarbonate:

$Fe\ (HCO_3)_2 + 2H_2O = FeO + 2CO_2 + 3H_2O$

$4FeO + O_2 = 2FeO_3$

$Fe_2O_3 + 3H_2O = 2Fe(OH)_3\downarrow$

In case of manganese,

$6Mn + 3O_2 + 6H_2O = 6MnO_2\downarrow + 12H$

1 mg of Mn requires 0.29 mg of O_2

Manganese removal requires a pH adjustment upto 9.4 to 9.6.

The oxidation can be accelerated by addition of alkaline substances such as lime, soda ash or caustic soda.

2. Iron and Manganese bound with organic matter:

• It is difficult to break the bond between them to cause their removal.

• The bond is broken by adding lime, and thereby increasing the pH of water to 8.5 to 9 so that iron and manganese can be precipitated; or by adding chlorine lo suping or potassium permanganate. Once the bond is broken, they can be removed by the aeration procedure as follow.

• Alternatively, the aerated water is allowed to trickle over contact beds of coke, gravel, crushed pyrolusite, followed by sedmentation and filtration.

• If organic acids are present; aeration, dosage with lime, sedimentation and filtration are effective.

3. Manganese Zeolite:

This medhod is adopted when water does not contain large amount of iron or dioxide. As raw water passes through the bed of zeolite, the iron and manganese are oxidised to insoluble hydrated oxides that are removed by filtration. After the zeolite becomes exhausted, it is regenerated by backwashing with potassium permanganate.

DEFLUORIDATION

• The optimum concentration of fluoride in drinking water should be 1 to 1.5 mg/l; (preferably 1 mg/l)

• It is believed that fluoride deficiency in water causes dental caries (weaker tooth and enamel) in children. It is also believed that fluoride stimulates bone formation, reduces hardening of arteries and also helps in the treatment of osteoporosis.

• Due to this belief, if water is deficient in fluoride, fluoride compounds ar added to water in the form of sodium fluoride (NaF), sodium Silico flourid (Na2SiF6) and hydro-fluosilicic acid (H2SiF), and this process is calle “Fluoridation”.

However, when the fluoride levels are in excess of 1 mg/l in water, it leads to th following abnormalities:

(i) Dental fluorosis - discoloured, blackened, mottled or chalky white teeth an pitting of enamel.

(ii) Skeletal fluorosis - Severe and permanent bone and joint deformations. (iii) Non-skeletal fluorosis :

• Gastro-intestinal problems (abdominal pain, diarrhoea, constipation)

• Neurological disorders (nervousness, excessive thirst, frequent urinatio Fluorosis can damage the foetus and also adversely affect the IQ of childre Fluorosis is an irreversible disease and it has no cure.

Therefore, the excess fluoride has to be removed from water. The technique removal of fluoride from water is known as “De-fluoridation”.

Methods of defluoridation:

The following technologies are generally used for removing flourides from wat bos

(1) Absorption by Activated Alumina (AA), commonly known as Prasa Technology;

(2) Iron Exchange Adsorption method;

(3) Nalgonda Technique; and

1. Prashanti Technique using adsorption by activated alumina (AA).

In this method, the raw water containing high contents of fluoride, is passed (percolated) through the insoluble granular beds of substance like Activated Alumina (AA), or Bone Char, or activated carbon, or serpentinite, or activated bauxite; which we adsorbs fluoride from the percolating water, giving out defluoridated water.

Activated alumina, is found to be an excellent medium for removal of excess fluoride. It is higly selective to fluoride in the presence of sulphates and chlorides, when compared to synthetic ion exchange resins.

The adsorption process is best carried out under slightly acidic conditions (pH = 5- 7); the lower value of pH is more effective for its removal.

The activated alumina, after becoming saturated with adsorbed fluoride, can be cleaned and regenerated by back washing with 1% caustic soda solution (NaOH).

2. Ion Exchange Adsorption Method :

The ion exchange process is similar to the zeolite process for removing hardness from water.

The process however, uses a strong base anion exchange resin (zeolite) in the chloride form. As the water passes through the bed of the resin contained in a pressure vessel, fluorides and other anions like arsenic, nitrates, etc., present in the water are exchaged with the chloride ions of the resin, thus releasing chlorides into water and adsorbing fluoride ions into the resin. The arsenic and nitrate ions also get removed in the process. When the resin gets saturated with anions like fluoride, nitrate, arsenic etc. the same can be cleaned and regenerated with 5-10% sodium chloride solution (brine), and the bed is returned to service.

During regeneration, the process gets reversed, as the anions absorbed on the resin get replaced by chloride ions and discharged into waste water.

The capacity of a plant based on this technology may range from 500 l/h to 5000 l/ h. The method ensures high efficiency of fluoride removal (besides removing nitrates, arsenic, etc.) But it requires regular replacement of resin, and large amount of salt (NaCl) for regeneration of resin. The method is very costly and “after sales service” in villages is poor. The safe disposal of waste water from regeneration, containing high concentrations of toxic fluoride, nitrate and arsenic ions etc. again poses serious problems.

3. Nalgonda Technique :

This technique is widely used in Indian villages. This technique is simple and economical than the ion-exchange processes, since it does not involve regeneration of media, and employs chemicals which are readily available, and easy to operate and maintain, using local skills. Nalgonda technique, not only helps in the removal of fluoride, but also helps in removing colour, odour, turbidity, bacteria and organic contaminants from raw supplies.

Nalgonda technique uses aluminium salt (alum) for removing fluoride. The raw water is firstly mixed with adequate amount of lime (CaO) or sodium carbonate abizo (Na2CO3) and thoroughly mixed. Alum solution is then added, and water is stirrred slowly for about 10 minutes, and allowed to settle for nearly one hour. Th precipitated sludge is discarded, and the clear supernatant containing permissibl amount of fluoride is withdrawn for use.

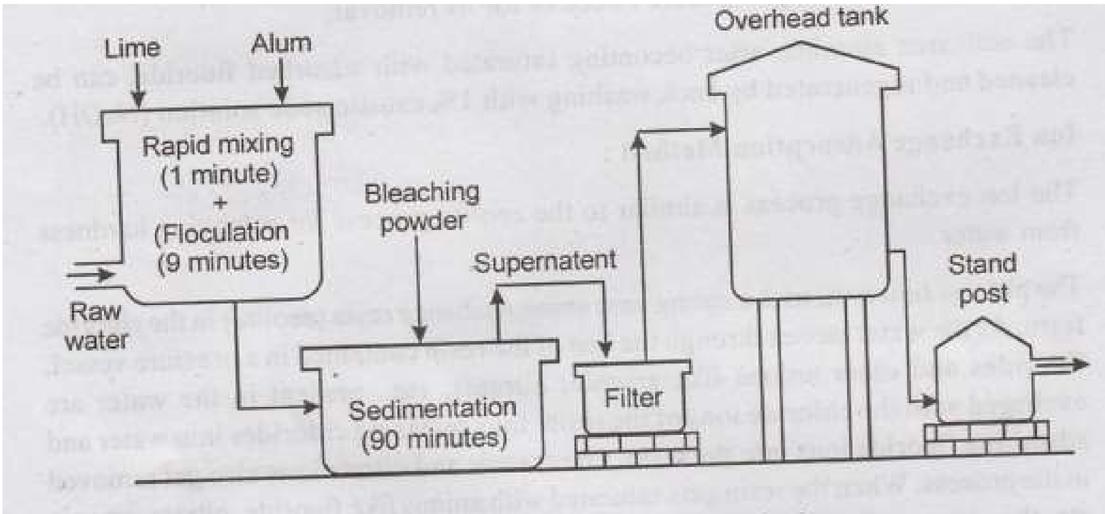


Fig. 2.22 Line diagram for Nalgonda Technology.

The added lime or sodium carbonate helps to ensure adequate alkalinity requi for effective hydrolysis of aluminium salts, so that the residual aluminium does remain in the treated water. Bleaxching powder is also generally added with li prior to the addition of alum, to achieve simultaneous disinfection of treated wa L00 and also to keep the system free from undesirable biological growth.

4. Reverse Osmosis Process :-In this method, the raw water is passed through a s permeable membrane barrier, which permits the flow of clear water through it and blocks the flow of salts including fluorides. This method is generally adop for desalination for removing salt from water and has been thoroughly explai under ‘Desalination’. This method is however rarely used solely for defluorida of village water supplies due to prohibitive high cost and poor after sales servic machines using such a treatment technology, although the method is capabl fficiency without the use of any chemicals.

Choosing a particular defluoridation method :

The choice of technology depends upon the fluoride levels in water and the volume of water to be fluoridated. The various merits -demerits of these technologies are also kept in view, which is illustrated in Table.

Table 2.2: Comparison of Available Technologies for Defluoridation.

Name of Technology	Process	Advantagesa	Disadvantages
1. Adsorption by activated Alumina (AA) commonly known as Prasanti Technology.	• In this process, raw water is passed through AA which adsorbs fluoride, passing out defluoridated water.	• Useful at community and household level. • Filters can be attached with hand-pumps or standposts • Low sludge formation.	• Cost is inhibiting for villagers • Regneration of AA poses problem • Poor after sales service in villages. • Fluoride reduction may not be upto non-toxic levels.
2. Ion Exchange Adsorption Method.	• In this process, resin is used to adsorb fluoride from water. • Capacity ranges from 500 litres per hour to 5,000 litres per hour.	• Useful at community and household level. • High fluoride removal efficiency.	• Regular replacement of resin. • Large amount of salts are involved in regeneration • Poor after sales service in villages
3. Nalgonda Technology	• In this process, alum and lime is added to raw water and stirred for 10 minutes. Fluoride gets adsorbed by alum, and flocs are formed. These flocs are allowed to settle down for 90 minutes, after which water is filtered.	• Useful at community and household level. • Cost Effective • Indigenous technology • Popular in India • Low capital cost	• Technical expertise required • Time consuming process • Disposal of flocs is a problem. • Alum dose needs regular calculation. • RMO cost is high.
4. Reverse Osmosis	• In this process, water is passed through a membrane which blocks fluoride flow, allowing only defluoridated water to pass.	• Different kind of membranes available • No chemicals added • High fluoride removal efficiency	• Cost inhibitive for villagers. • Poor after sales service in villages.

SOFTENING

• The reduction or removal of hardness from water is called water softening.

• Hard water causes the following problems :-

(i) It causes more consumption of soap in laundry work.

(ii) It causes modification of colours and affects the dyeing industries.

(iii) It causes serious difficulties in the manufacturing process such as paper making, al grind ice manufacture, Rayon industry etc.

(iv) It causes choking and clogging of plumbing fixtures.

(v) It causes scale formation in boilers and hot water heating system.

(vi) It makes the food tasteless, tough or rubbery.

Table 2.2: Classification of Hardness of water

Classification	Total hardness as mg/l (ppm) of $CaCO_3$
1. Soft water	50
2. Moderately hard water	50 – 150
3. Hard water	150 – 300
4. Very hard water	300

Objectives of water softening are:

(i) To reduce the soap consumption of water

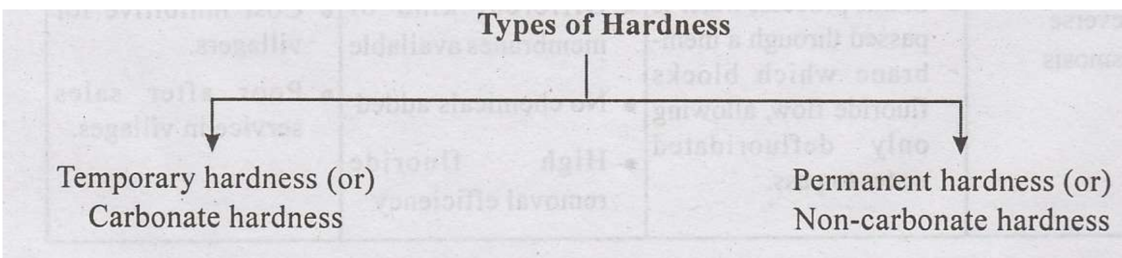
(ii) Improve the food taste

(iii) To reduce the maintenance of plumbing fixtures

(iv) Prevent scaling of boilers

(v) Improves the efficiency of manufacturing and dying processes.

(vi) Improves the efficiency of filtration etc.



• Temporary/Carbonate Hardness - is caused by the carbonates and bicarbonates of calcium and magnessium. Temporary hardness can be easily removed by boiling or adding lime.

• Permanent / Non-carbonate Hardness is caused by the sulphates, chlorides, nitrates of Calcium and Magnesium. This cannot be easily removed and requires special methods of water softening such as lime-soda process, Zeolite process or Demineralisation.

Methods of removing Temporary Hardness :-

1. Boiling:

• Calcium carbonate is not readily soluble in water.

• It may exist as Calcium bicarbonate in water, which easily dissolves in water containing Carbon dioxide.

• When the water is boiled, CO2 is released, leading to precipitation of CaCO3 which can be removed by sedimentation process in a settling tank.

$$Ca(HCO_3)_2 + \text{Heat} \longrightarrow CaCO_3\downarrow + CO_2\uparrow + H_2O$$

Calcium bicarbonate (Soluble) — Calcium carbonate (Insoluble)

• This method cannot be used for Magnesium carbonate and Magnesium bicarbonate, since MgCO3 is soluble in water.

Limitation:

• Boiling does not remove temporary hardness caused by magnesium.

• Boiling is unfeasible and uneconomical for public water supplies.

2. Addition of Lime

Lime (CaO), generally hydrated lime [Ca(OH)2] is added to the water. The following reactions take place :

$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCO_3\downarrow$$

MgCO₃	Ca(OH)₂	Mg(OH)₂	CaCO₃
Magnesium carbonate (soluble)	Hydrated lime	Magnesium hydroxide (insoluble)	Calcium Carbonate (insoluble)

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Ca(HCO_3)_2 + Mg(OH)_2)\downarrow$$

Magnesium

The calcium carbonate and magnesium hydroxide are precipitated which can be removed in the sedimentation tank.

Methods of removing Permanent Hardness:

The different methods of removing permanent hardness are :

(1) Lime - soda process

(2) Base - Exchange process/ Zeolite process

(3) Demineralisation process

1. Lime - Soda process:

• In this process, lime [Ca(OH)2] and soda ash [Na2 CO3] are added to hard water; which react with calcium and magnesium salts, to form insoluble precipitates of calcium carbonate and magnesium hydroxide.

• These precipiates can be sedimented out in a sedimentation tank.

• The chemical reactions which takes place are :

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$$
$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow Ca(HCO_3)_2\downarrow + Mg(OH)_2\downarrow$$
$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaCO_3\downarrow$$
$$MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaCl_2$$
$$MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaSO_4$$
$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O$$
$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaCl$$
$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\downarrow + Na_2SO_4$$

This process removes the following:

• Carbonate hardness (both Ca and Mg)

• Non-carbonate hardness of Mg is converted into non carbonate hardness Ca, which is removed by soda.

• Removes free dissolved CO2

• Equipments required for this process are :(Similar to coagulation process)

(i) Miving Tank - Lime and soda ash are added to raw water and mixe

(ii) Flocculation

(iii) Sedimentation - The precipitates formed are made to settle in the tank. The detention time varies between 2 to 4 hours.

• The dosage of lime and soda required for softening, depends upon the chemical quality of water and the extent of hardness removal desired.

Advantages of Lime -soda process:

• Economical

• Easily combined with other water treatment methods.

• Lime and soda used in combination with coagulants, reduces the dosage of coagulants.

• Increases pH of water and thus reduces corrosion of pipes.

• Increases pH which kills the pathogens.

• Reduces mineral content of water.

• Removes iron and manganese to some extent.

Disadvantages of Lime-soda process:

• Large quantity of sludge, precipitates of CaCO, and Mg(OH), is formed, which requires proper disposal.

• Careful operation and skilled supervision is required.

• Recarbonation of water is required; otherwise it will cause incrustation of pipe walls. (siiloss beau)

• Zero hardness cannot be achieved. Hardness removal is only upto 50 mg/l.

Recarbonation of softened water:

The very fine precipitates of calcium carbonate and magnesium hydroxide, may sometimes not settle in the sedimentation tank. These particles may deposit on filters and cause enlargement of sand grains i.e. incrustation of filter media and distribution pipes.

To prevent this, the softened water leaving the sedimentation tank should be recarbonated by passing carbon dioxide gas.

In Recarbonation process, the insoluable carbonates combine with carbon dioxide to form soluable bicarbonates.

$$\underset{\text{(Insoluble)}}{CaCO_3\downarrow} + CO_2 + H_2O \longrightarrow \underset{\text{(soluble)}}{Ca(HCO_3)_2}$$

The CO2 gas to be blown in water can be produced by burning coke, gas or oil.

2. Zeolite or Base-exchange or Cation-exchange Process:

• Zeolite are naturai salts or clays, hydrated silicates of sodium and aluminium, Issimodo or synthetic resins.

• General formula is :

$$Na_2\,OAl_2O_3\,x.\,SiO_2\,y.\,H_2O$$

Where $x = 2$ or more,

$y =$ varies

• Zeolites have the property of exchanging their cations.

• During water softening, Sodium ions of zeolite are exchanged with Calcium and Magnesium ions in hard waters.

• The chemical reactions involved are:

$$\underset{\text{Sodium Zeolite}}{Na_2Z} + \underset{\text{Calcium or Mg salts}}{\begin{matrix}Ca\\Mg\end{matrix}\left\{\begin{matrix}(HCO_3)_2\\SO_4\\Cl_2\end{matrix}\right.} \longrightarrow \underset{\text{Sodium salts}}{Na_2\left\{\begin{matrix}(HCO_3)_2\\SO_4\\Cl_2\end{matrix}\right.} + \underset{\substack{\text{Ca or Mg}\\\text{zeolite}\\\text{(used zeolite)}}}{\begin{matrix}Ca\\Mg\end{matrix}\left\{Z\right.}$$

• The Ca and Mg zeolite is regenerated by treating with 5 to 10% solution of sodium chloride (Brine solution)

$$\underset{\substack{\text{Used}\\\text{Zeolite}}}{\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Z} + \underset{\substack{\text{Sodium}\\\text{Chloride}\\\text{Solution}}}{2NaCl} \rightarrow \underset{\substack{\text{Regenerated}\\\text{Zeolite}}}{Na_2Z} + \left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Cl_2$$

• A zeolite softener resembles a sand filter in which the filtering media is zeolite. They may be either gravity filters or pressure filters. The pressure filter type zeolite softener commonly used is shown in figure 2.23. It consists of a closed steel cylinder containing a bed of zeolite (0.75m to 2m thick). The hard water 300 litres per sq.m per minute (0.1 to 0.3m/min) When the sodium salts of zeolite are exhausted, it is regenerated by backwashing with 10% brine solution with 10% bri (Nacl).

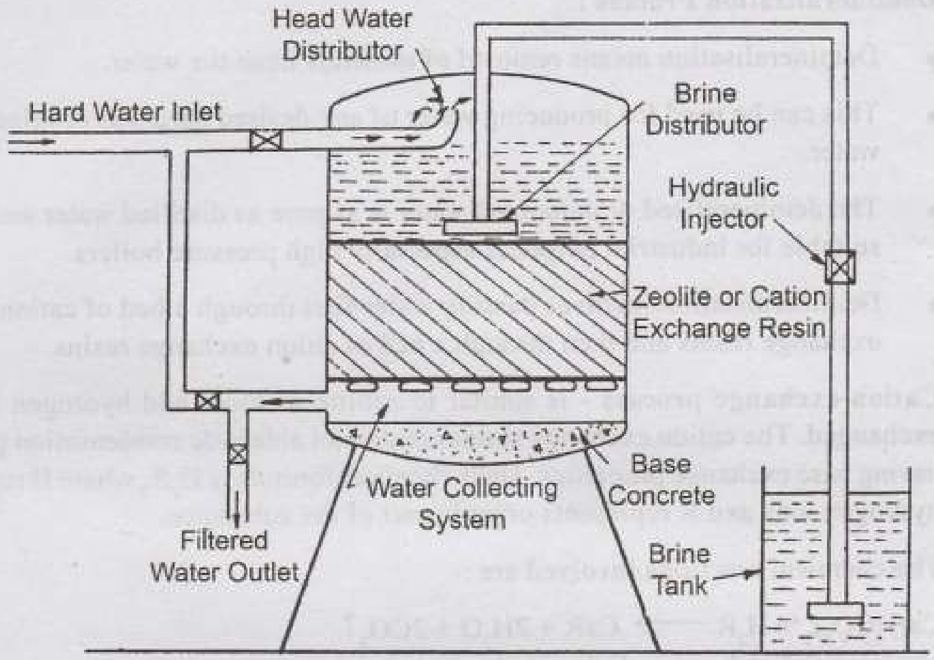


Fig. 2.23 Zeolite water Softener (Pressure filter type)

Advantages

(i) Water of zero hardness can be achieved; useful for textile industries, boilers

(ii) Plant is compact, automatic, easy to operate.

(iii) No sludge is formed. No problem of sludge disposal.

(iv) RMO (Running, Maintenance and operation) cost is less.

(v) Also removes iron and manganese from water.

(vi) No problem of incrustation of pipes.

Disadvantages:

(i) Not suitable for treating turbid waters.

(ii) Process leaves sodium bicarbonate in water, which causes foaming in industrial or boiler feed waters.

(iii) Costly and not suitable for treating water containing iron and manganese iron or manganese zeolite cannot be regenerated back into sodium zeolit zeolite gets wasted.

3. Demineralisation Process:

• Demineralisation means removal of minerals from the water.

• This can be used for producing water of any desired hardness or mineral

• The demineralised or deionized water is as pure as distilled water and suitable for industrial purposes especially high pressure boilers.

• Demineralisation involves passing water first through a bed of cation exchange resins and then through a bed of anion exchange resins.

(a) Cation-exchange process - is similar to zeolite method, and hydrogen ion exchanged. The cation exchange resins are phenol aldehyde condensation pro having base exchange properties. Their chemical formula is H,R, where H repre hydrogen ions and R represents organic part of the substance.

The chemical reactions involved are :-

$$\underset{}{Ca(HCO_3)_2} + \underset{\text{Fresh resin}}{H_2R} \longrightarrow \underset{\text{Exhausted resin}}{CaR} + 2H_2O + 2CO_2\uparrow$$

$$CaCl_2 + H_2R \longrightarrow CaR + 2HCl$$

$$MgSO_4 + H_2R \longrightarrow MgR + H_2SO_4$$

$$2NaCl + H_2R \longrightarrow Na_2R + 2HCl$$

In the cation exchange process, acids [carbonic acid, hydrochloric acid, sulp acid etc.] are formed, which are removed by the subsequent anion exchange pro

(b) Anion - exchange Process:

The anion-exchange resins are condensation products of amines with formalde with anion exchange properties i.e., hydroxyl ions (OH) is exchanged. The cher formula of resin is ROH, where OH represents hydroxyl ions and R represents org part of the substance.

The chemical reactions involved are:

ROH + HC1 →RCI + HOH

2ROH + H2SO4 → R2SO4+2HOH

The water coming out from the anion-exchanger will be free from minerals. ziwiadio

When the resins get exhausted, regeneration is done as follows:

(i) Regeneration of cation exchange resin - By treating with dilute hydrochloric acid or sulphuric acid.

$$\left.\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right\} R + 2HCl \longrightarrow H_2R + \left.\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right\} Cl_2$$

Exhausted cation exchange resin — Rgenerated Cation exchange resin

$$\left.\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right\} R + H_2SO_4 \longrightarrow H_2R + \left.\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right\} SO_4$$

Exhausted resin — Regenerated resin

(ii) Regeneration of anion-exchange resin - By treating with sodium carbonate solution. 2RCI+ Na2CO3 + 2H2O → 2ROH + 2NaCl + CO2↑ + H2O

$$2RCl + Na_2CO_3 + 2H_2O \longrightarrow 2ROH + 2NaCl + CO_2\uparrow + H_2O$$

Exhausted anion resin — Regenerated anion resin

Problem 2.6:

Comparison of Lime-soda and Zeolite processes of water softening

Table 2.4: Comparison of water softening methods:

Item	Lime Soda Process	Zeolite Process
• Size of plant	Large and Bulky	Small and Compact
• Skilled supervision	Required	Automatic and easy operation
• Sludege troubles	Large sludge is formed, posing disposal problems.	No sludge is formed No sludge disposal problems
• Post treatment, if needed	Recarbonation is must after sedimentation and filtration Otherwise, Incrustation of pipes will occur.	Not required
• Results obtained	Water of hardness 50 mg/l. Useful for public supplies	Zero hardness. Useful for Industrial supplies.
• Removal of Colour due to Iron and Manganese	Only to small extent	Removal is costly.
• pH of water	Increases pH which reduces corrosion of pipe	pH of water does not change
• Effects on Bacteria	Kills pathogens	No effect.
• Care in Material Handling	Careful handling is required as lime and soda are corrosive	Brine solution does not require much care
• Economy	Economical and can be combined with other water treatments without extra cost.	Costlier
• Hardness which can be treated	Excessively hard waters can be treated	Hardness < 800 mg/l only can be treated easily and economically
• Turbidity of raw water	Highly turbid/acidic waters can be treated	Turbid waters canot be treated

Design a zeolite-softener for an industry, using the following data:

(i) Quantity of soft water required per hour = 25,000 litres.

(ii) Hardness present in raw water as CaCO, = 400 ppm

(iii) Hardness to be obtained in the treated supplies = 50 ppm

(iv) Ion exchange capacity of zeolite = 10 kg of hardness per cu.m of zeolite

(v) Salt required for regeneration of exhausted zeolite

= 50 kg per cum of zeolite.

Also assume that the industry works for 2 shifts of 8 hours each, per day. M suitable assumption wherever needed.

Solution :

• Quantity of soft water required per shift of 8 hrs.

= 25,000 1/hr × 8 hr = 2,00,000 litres.

• Hardness removal is upto 50 ppm out of total hardness of 400 ppm.

• Percentage removal desired= 350/400 x100=87.5%

• As the zeolite process reduces the hardness to zero; a part (87.5%) of raw water is treated to obtain zero hardness and the balance (12.5%) is not treated and added as raw water, to achieve hardness of 50 ppm.

The quantity of water to be treated per shift

= 2 x 105 x 0.875 1.75 x 105 litres

The amount of hardness to be removed per shift

= [Quantity of water treated per shift in litres] x [hardness in mg/l]

= (1.75 x 105) × 400 mg/l

= 70 x 106 mg = 70 kg.

The quantity of zeolite resin required

Hardness to be removed in Kg / Ion-exchange capacity of resin in Kg/cu.m

= 70 Kg / 10Kg/cu.m = 7 cu.m

Assume number of units as 6 with one unit as standby.

Volumt of one unit = 7 cu.m / 5 =1.4 cum

Provide 6 (5+1 standby) units with volume 1.4 cum, i.e. of area = 1m2 and depth =

Regeneration:

In 8 hours of shift time, assume regeneration process will take one hour and the

The quantity of salt required for regeneration

= 50 kg/cum of zeolite

= 50 kg/cum x 7 cum

= 350 kg.

Using 10% brine solution (10 kg salt dissolved in water to make 100 kg solution

350 kg of salt will produce

350×100/10 = 3500 kg of water solution

= 3500 kg /1000kg/m3 =3.5 cum

Provide two tanks of 1.75 cu.m capacity each. Assume the diameter of tank as m, then the depth required

$$=\frac{1.75}{\frac{\pi}{4}(1.2)^2}=1.55m$$

Using free board = 0.15, Overall depth = 1.55 + 0.15 = 1.7m

Overall tank size will be = 1.2 m dia x 1.7 m depth

Check for contact period

Flow rate over zeolite bed

= volume of water treated per shift /operation hours of zeolite

= 1.75×105 /7 litres/hr =25,000 litres/hr

Rate of filtration = Flow rate of water over zeolite bed / surface area of zeolite

= 5,000-83.31/m2/min

= 0.083 m/minute > 0.3 m/min

It is less than 0.3 m/min, Hence OK.

Contact period (i.e. Average time of travel through the bed)

= Depth / rate of filtration = 1.4 m/ 0.083 m/min

= 16.9 minutes > 7.5 minutes

Hence design is OK

DESALINATION PROCESS

• Only 0.5% of the earth's water is potable. The remaining 97% is ocean water and 2.5% is brakish water.

• Natural water can be classified according to their TDS values.

Table 2.5: Classification of salty waters

S.No.	Type of water	TDS in mg/l
1	Sweet water	0 – 1000
2	Brackish water	1000 – 5000
3	Moderately saline water	5000 – 10,000
4	Severly saline water	10,000 – 30,000
5	Sea water	Above 30,000

Due to the scarcity of fresh water, it has become necessary to convert salt water into potable fresh water, and the process is called Desalination. It also reduces the Total Dissolved Solids (TDS) in water.

Desalination is a costly process. The water obtained by desalination proves much costlier than the naturally available - treated water. Research is going on to reduce the cost of desalination.

Methods of Desalination:

The various methods which are generally adopted for the conversion of salt water into fresh water are enumerated below:

(1) Desalination by evaporation and distillation.

(2) Electrodialysis method

(3) Reverse Osmosis method

(4) Freezing process

(5) Solar distillation method and

(6) Other methods.

1. Desalination by evaporation and distillation:

This is the most commonly used method of desalination. In this method, Sea or saline water is boiled in giant vessels called evaporators, to produce water vapours which are caught and condensed into fresh water.

• An evaporator consists of a metal box in which the salt water (brine) is heated by a nest of pipes carrying very hot steam.

• Heat passes from the steam through the pipe walls and boils the brine.

• The boiling brine evaporates and the vapour is led into a second box, where another nest of pipes, filled with cold brine, condenses it to fresh and pure water. The heat coming out from the vapour, during cooling operation, warms the cold brine, which is then sent to the evaporator.

• These evaporators are efficient but are prone to ‘scaling’. The scale consists of lime stone, chalk and plaster of paris, which gets deposited on the metal box evaporator. This problem is overcome by pretreatment of the raw brine (salt water) through pH control and decarbonation or by lining the evaporator tubes with teflon.

In order to reduce the cost of distillation, the following new methods have been developed to conserve the heat energy and fuel used in the process:

(i) Vertical Tube Evaporators (VTE)

(ii) Multistage Flash Evaporators (MSF)

(iii) Multieffect Multistage flash evaporators (MEMS)

(iv) Combined process (VTE / MSF)

Vertical Tube Evaporators (VTE)

• A single effect evaporator is shown in Figure.2.24 oil to aboston

• The The steam from boiler heats and vaporises the salt water.

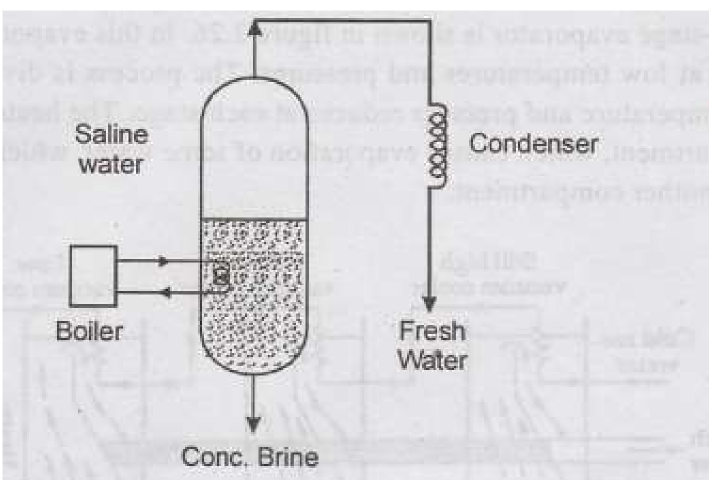


Fig. 2.24 Single Effect Vertical Tube Evaporator

A Multiple Effect Evaporator is shown in Figure 2.25. In this, the water evaporates at the highest pressure in the first effect. The vapour is condensed in the second effect to evaporate an equal amount of vapour. Similarly, the third evaporator acts as condenser for the second and so on. The temperature and pressures in the successive evaporators will go on reducing so that salt water may boil at low temperature and pressure.

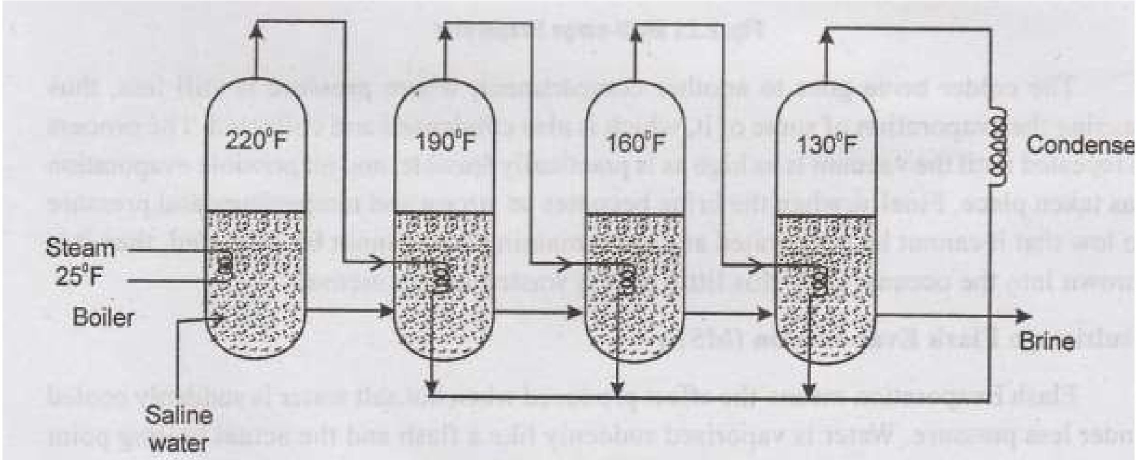


Fig. 2.25 Multiple Effect Evaporator

Multistage Evaporation

Water can be boiled at low temperatures, by reducing the pressure. The hot brine can be vaporised to a certain extent at a certain pressure; the colder brine left can also be vaporised at still lower pressures and so on. This principle is used in 'multi-stage' evaporators i.e. water is evaporated - condensed again and again in various stages. This technique efficiently utilises the heat energy.

A multi-stage evaporator is shown in figure 2.26. In this evaporator, the operation is carried out at low temperatures and pressures. The process is divided into different stages. The temperature and pressure reduces at each stage. The heated brine is led into the first compartment, which causes evaporation of some water, which is condensed and collected in another compartment.

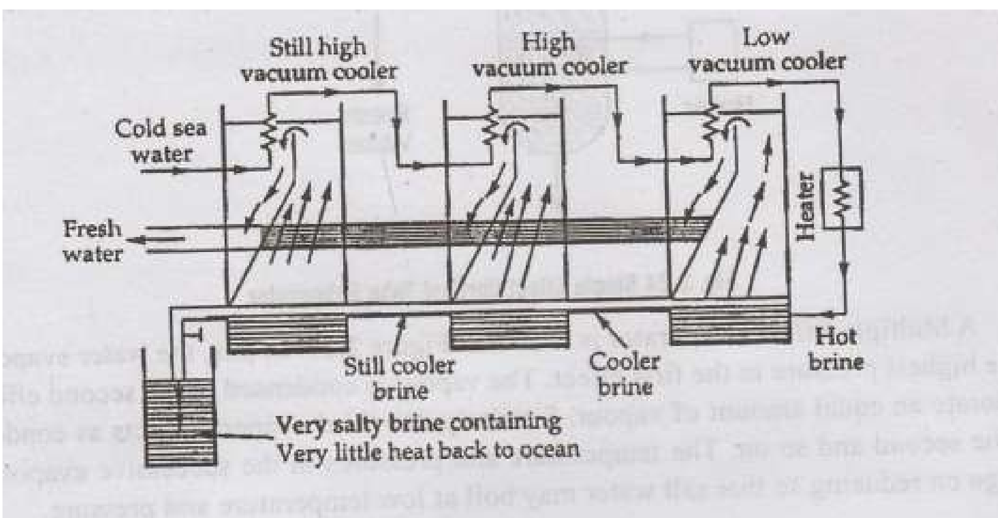


Fig. 2.26 Multi-stage Evaporator

The colder brine goes to another compartment, where pressure is still less, thus causing the evaporation of some of it, which is also condensed and collected. The process is repeated until the vacuum is as high as is practically feasible, and all possible evaporation has taken place. Finally, when the brine becomes so strong and temperature and pressure so low that it cannot be evaporated and the remaining heat cannot be extracted, then it is thrown into the oceans. Only this little heat is wasted in this method.

Multistage Flash Evaporation (MSF)

Flash Evaporation means the effect produced when hot salt water is suddenly cooled under less pressure. Water is vaporised suddenly like a flash and the actual boiling point is never reached.

The salt water is heated to the highest temperature using a heater. The hot brine under pressure is sprayed through nozzle into the first chamber which is at a lower pressure and cooler. The sudden change produces the flash action and the water will evaporate immediately. The salt water passes through a number of compartments (flash chambers) wherein flashing of the brine occurs at successively low pressures. The vapour released in flashing each stage condenses to heat the incoming sea water and gives fresh water

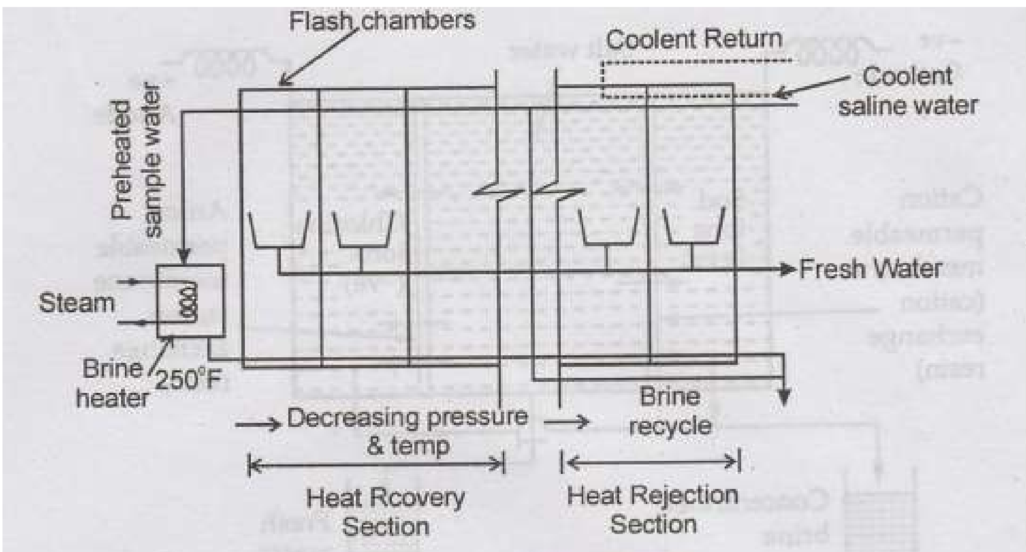


Fig. 2.27 Flash Evaporation-Multistage

Multieffect Multistage Flash Evaporation (MEMS)

In this method, the overall temperature flashing range is broken into a number of temperature intervals. Within each interval, an individual single-effect multistage unit with its own heat input, heat recovery, heat rejection and recycling stream operates. The first effect receives heat from the external source while for the subsequent effects, the heat from the previous effect is rejected to the brine of the next effect. This utilises the heat input efficiently.

2. Desalination by Electrodialysis method:

In salt water, H,O molecules are bonded together with sodium and chlorine ions. These hydrogen-bonds between the H2O molecules and Na+ and Cl- ions must be broken up, in order to separate the salt from water. These bonds where broken by heat in the “method of distillation”; while in the “electrodialysis method”, these bonds are broken with the help of electricity.

When an electric-current is passed through the salt-solution, the sodium and chlorine ions get freed from water molecules, and they start moving towards their oppositely charged electric poles. In other words, the +vely charged sodium ions will move towards the - ve pole.i.e., cathode, and the - vely charged chlorine ions will move towards the +ve anode. If these cations (+ ve ions) and anions (- ve ions) are allowed to segregate in different compartments, what is left, is fresh-water.

The segregation is achieved by means of thin plastic like sheets called 'membranes'.

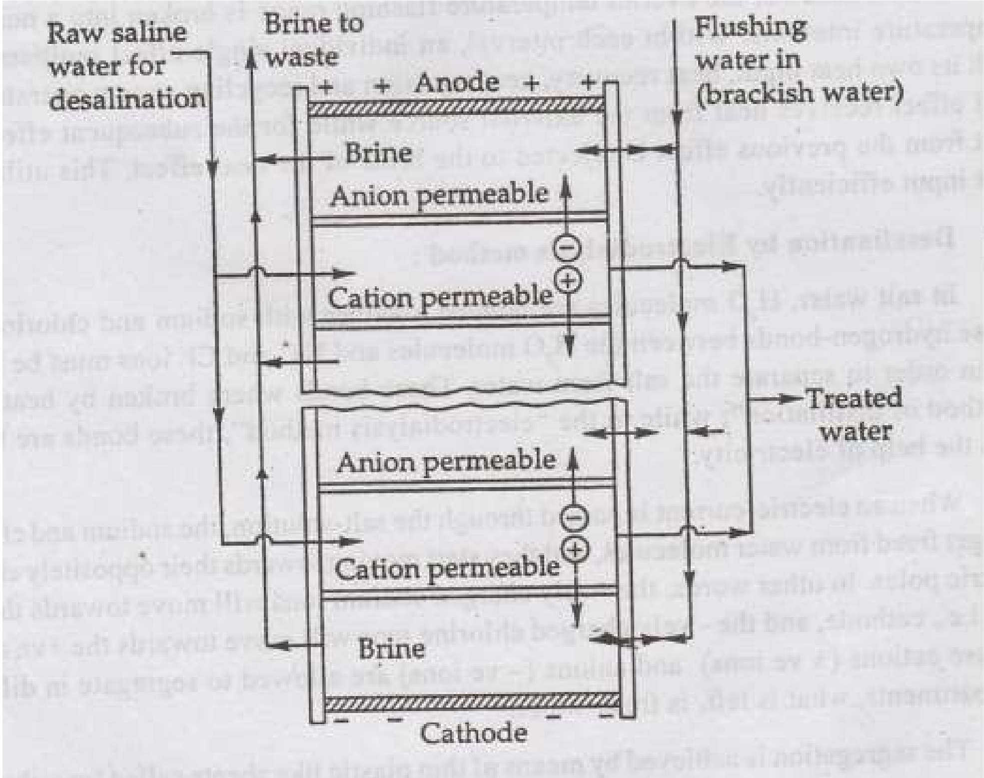


Fig. 2.29 Electrodialysis - showing a stack

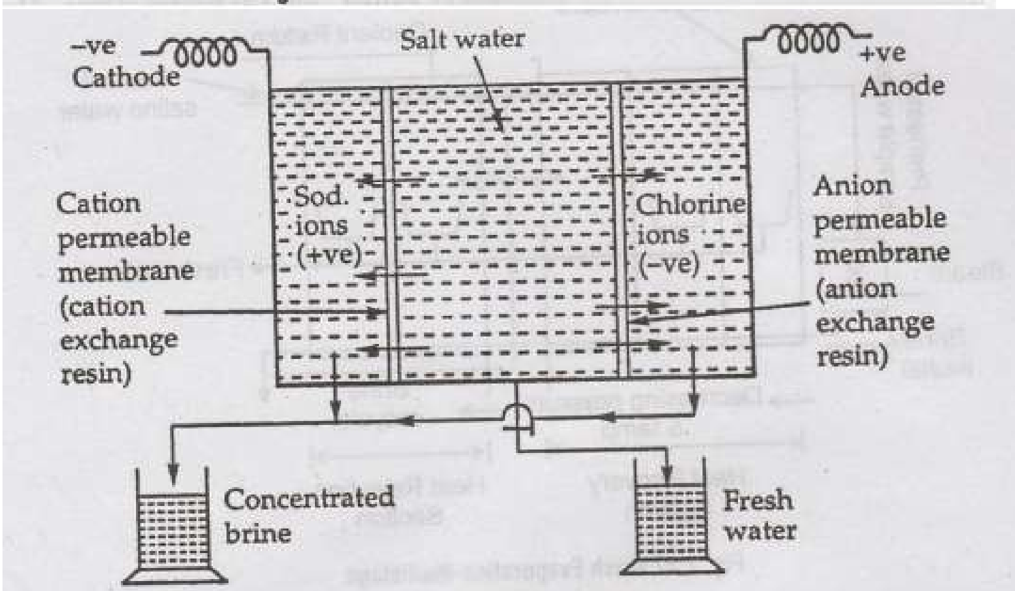


Fig. 2.28 Electrodialysis

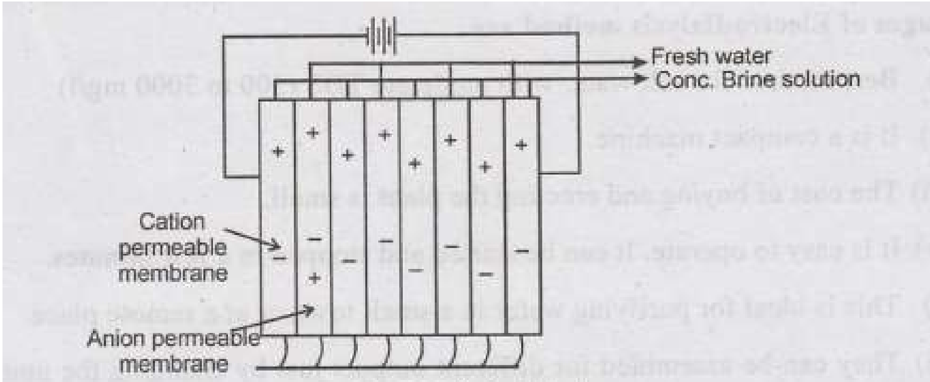
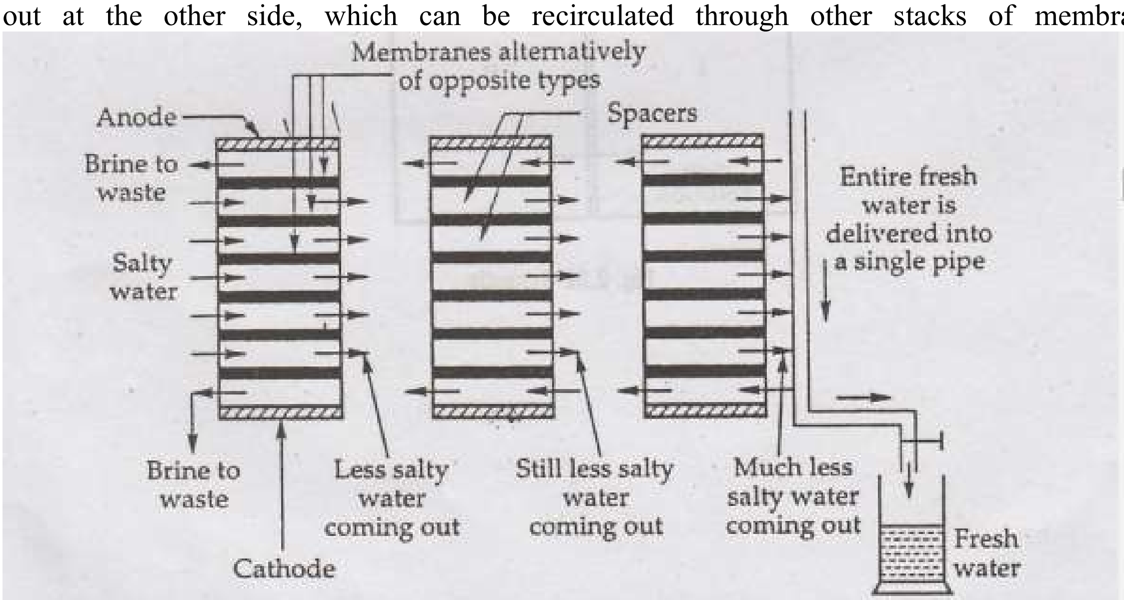


Fig. 2.30 Electrodialysis

A cell consists of a pair of cation and anion membranes installed in parallel between a pair of electrodes.

A stack consists of a number of membrane pairs installed parallel between a pair of electrodes (with spacers between each membrane).

For a big plant, stacks are hydraulically connected together, usually in parallel (sometimes in series, also), as shown in figure 2.31. In such a plant, therefore, a large number of small separations are hooked up together in parallel; and alternate kinds of membrane are stacked with thin spacers in between each pair of opposites. Pores give excess at each level, so that salt water could be forced in between the membranes, while less salty water could be pumped out at the other side, which can be recirculated through other stacks of membranes. Since one stack of membranes usually removes 50% salinity, very fine water could be produced in this manner, using three to four stacks.



Advantages of Electrodialysis method are:

(i) Best method for salt water with moderate TDS (500 to 3000 mg/l)

(ii) It is a compact machine.

(iii) The cost of buying and erecting the plant is small.

(iv) It is easy to operate. It can be started and stopped in a few minutes.

(v) This is ideal for purifying water in a small town or at a remote place.

(vi) They can be assembled for different outputs just by changing the number of units added together.

3. Desalination by Reverse Osmosis process :

In this method of desalination, the water molecules and the salt ions are separated by forcing the salt solution against a ‘semi-permeable membrane’ barrier, which permits the flow of water through itself but stops the salt. In Osmosis, when salt solution is separated from pure water by a semipermeable membrane, the pure water flows across the membrane until the pressure on the pure water side become equal to the osmotic pressure of the salt solution.

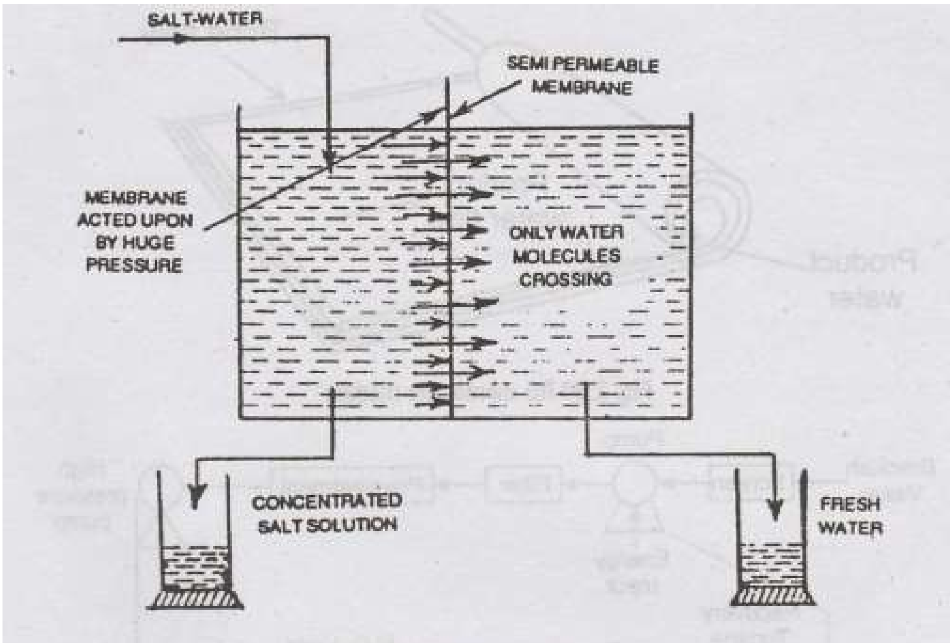


Fig. 2.33 Reverse Osmosis

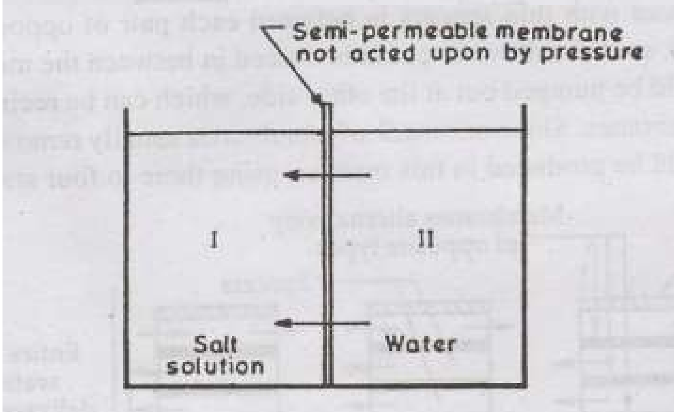


Fig. 2.32 Osmosis

But in reverse osmosis, the natural osmotic pressure is opposed by applying an external high pressure on the side containing the salt solution. In other words, the natural osmosis process is reversed, the external pressure forces pure water from salt solution to move across the membrane towards the side containing pure water.

The external pressure applied should be atleast twice the osmotic pressure to achieve

But in reverse osmosis, the natural osmotic pressure is opposed by applying an external high pressure on the side containing the salt solution. In other words, the natural osmosis process is reversed, the external pressure forces pure water from salt solution to move across the membrane towards the side containing pure water.

The external pressure applied should be atleast twice the osmotic pressure to achieve

a feasible flow. RO is usually operated at about 1000 Kg/cm2

The semi-permeable membranes are thin but dense and strong enough to withstand the high external pressure.

The classification of membranes based on pore size and particle size removed, is given below:

(i) Micro filtration (MF)

(ii) Ultra filtration (UF)

(iii) Nano filtration (NF); and

(iv) Reverse Osmosis (RO)

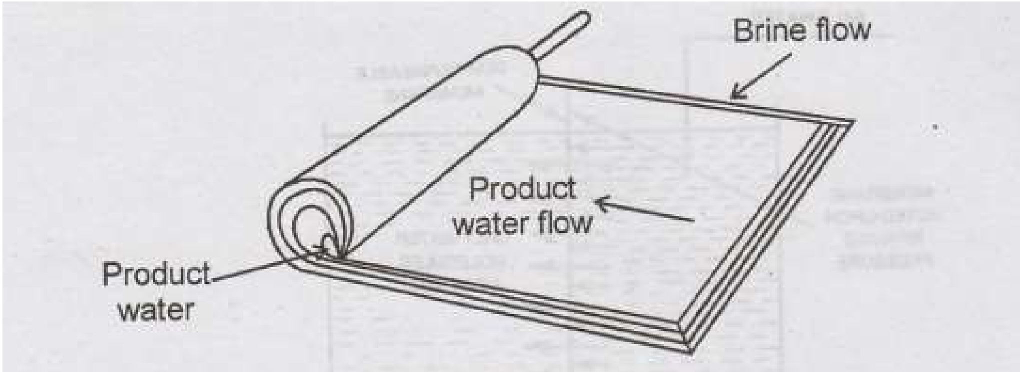


Fig. 2.34 RO membrane module

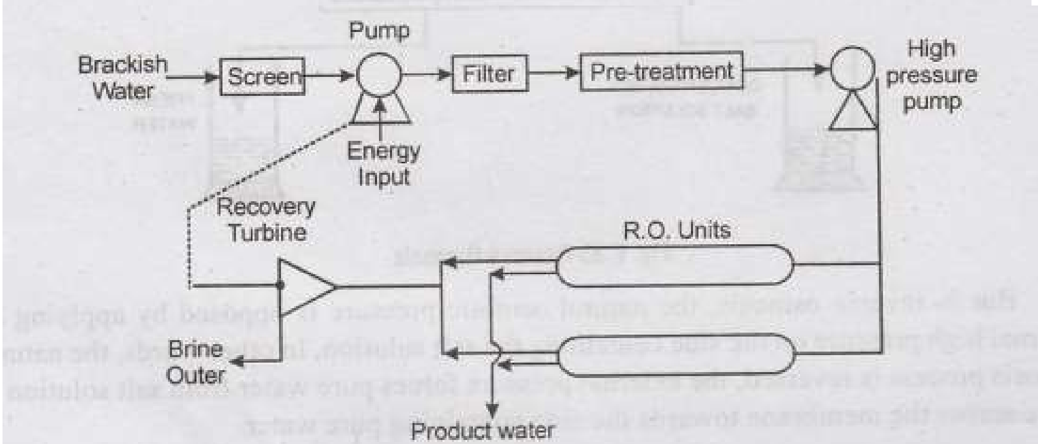
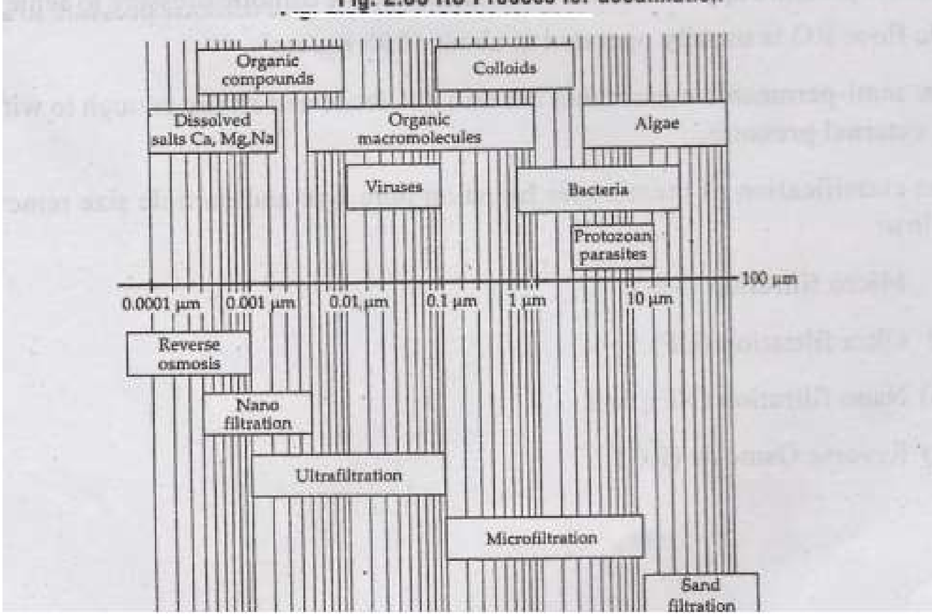


Fig. 2.35 RO Process for desalination



• Microfiltration (MF) and Ultra Filtration (UF) are microporous membranes which remove suspended small size particles by physical separation. They are low pressure processes.

• Nano filtration (NF) and Reverse Osmosis (RO) remove dissolved salts ions by osmosis. NF is known as low-pressure reverse osmosis. NF and RO are high pressure processes and the separation is by diffusion. RO rejects particles of size 0.0001 μm, whereas NF rejects particles of size greater than 0.001 μm (nanometer)

Reverse Osmosis can be used for desalination with low pressure membranes (as Nano filtration) of moderately salty waters (TDS of 1000 to 10000 mg/l); and with high pressure membranes for severely saline waters containing TDS above 10000 mg/l. Sufficiently good quality water containing TDS within 500 mg/l can be obtained by this method.

4. Desalination by Freezing process: This method is based upon the principle that when salt water freezes, the ice formed in the beginning is almost free from salt. This ice, when melted, can give us good water. The quality of water obtained is 20 satisfactory, but the cost of production is high and prohibitive. A freezing process involves cooling of the incoming sea water, freezing it to ice, separating the ice and brine liquor, melting the ice to give fresh water and using the concentrated brine to chill the incoming sea water. Liquefied hydrocarbons (n-butane) can be used as refrigerants. In direct contact refrigerating system, the refrigerated butane is mixed with the salt water. Alternatively, pressure freezing; a high-boiling hydrocarbon is frozen and mixed with prechilled sea water.

5. Desalination by Solar Evaporation Method :

The other desalination methods use thermal energy or mechanical power. But solar evaporation uses solar radiation as the source of heat energy. The equipment required is simple. The figure 2.37 shows a green-house type still, which may yield about 5 kg of fresh water/day/m2 of basin surface, under good sunshine conditions. Salt water is contained in a blacked bottom shallow through which absorbs the solar energy. The vapours rise and condence on the glass or plastic surface, so inclined as to cause the collected water to flow to a common reservoir. The glass surface must be frequently cleaned off dust etc. to keep them transparent.

6. Other methods of desalination: In this method, propane gas is allowed to combine with salt water under controlled conditions of temperature and pressure. A chemical reaction takes place between salt water and propane gas at temperatures higher than the freezing point of water, forming ice like crystals. These crystals reject the salt and accept only pure water in their composition. These crystals are separated from the brine, washed and decomposed to form water. The propane gas released

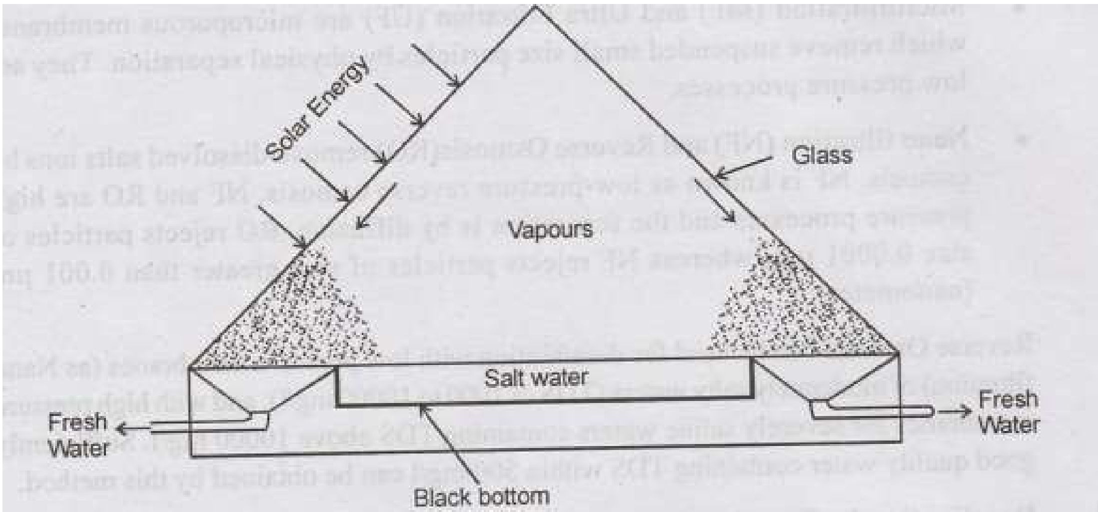


Fig. 2.37 Green-house type still solar Distrillation Method

Selection of a particular method of Desalination :

2200 Selection of the correct process, especially in the 500 - 5000 mg/l range (TDS), requires careful evaluation of process efficiency, plant capital and running cost. The application of the various desalination processes has been in the following categories of TDS waters.

Table 2.6: Choice of Desalination process for various Grades of Salty Water

S.No.	Desalination Process	TDS value of salty water to be treated in mg/l
1	Ion exchange	up to 500
2	Electrodialysis	500 – 3000
3	Low pressure Osmosis including nano filtration	1000 – 10000
4	High pressure Reverse Osmosis	10,000 and above
5	Distillation	Above 30,000

Distillation and reverse osmosis have been widely used. Almost 75% of all desalination plants are based on distillation.

RESIDUE MANAGEMENT

Water treatment plants produce a wide variety of waste products as well as safe and gaseous forms depending on the source of raw water and the type of treatment processes, commonly, coagulation/filtration, precipitative softening plant, membrane separation, ion exchange, granular activated carbon. The differences between the unit processes of the five plant types listed above characterize the type of residuals generated at a given facility. In the current regulatory climate, a complete management program for a water treatment facility should include the development of a cost-effective plan to remove and dispose of residuals.

The following steps need to be considered when developing a comprehensive water treatment residuals management plan:

• Characterize form, quantity, and quality of the residuals;

• Determine appropriate regulatory requirements;

• Select appropriate residuals processing/ treatment technologies; and

• Develop a residuals management strategy that meets both the economic and noneconomic goals established for a water treatment facility.

What are the residuals categories?

Water treatment plant residuals form when suspended solids in the raw water react with chemicals (e.g., coagulants) added in the treatment processes and associated process control chemicals (e.g., lime). Some potable water treatment processes generate residuals that are relatively easy to process and dispose. For example, leaves, limbs, logs, plastic bottles, and other large floating debris separated from water during the initial screening process can be disposed of at conventional solid waste landfills. However, most other treatment processes produce more complex residual waste streams that may require advanced processing and disposal methods to protect human health and the environment.

• The four major types of residuals produced from water treatment processes are:

• Sludges (i.e., water that contains suspended solids from the source water and the reaction products of chemicals added in the treatment process). Pre sedimentation, coagulation, filter backwashing operations, lime softening, iron 1800 and manganese removal, and slow sand and diatomaceous earth filtration all produce sludge.

• Concentrate (brines) from ion exchange regeneration and salt water conversion, membrane reject water and spent backwash, and activated alumina waste regenerate.

• Ione exchange resins, spent granular activated carbon (GAC), and spent filter media (including sand, coal, or diatomaceous earth from filtration plants).

• Air emissions (off-gases from air stripping, odor control units, or ozone destruction).

COAGULATION/FILTRATION

Typical Residual Waste Streams Generated	Typical Contaminant Categories	Typical Disposal Methods	Regulation Covering Disposal Method
Aluminum hydroxide, ferric hydroxide, or polyaluminum chloride sludge with raw water suspended solids, polymer and natural organic matter (sedimentation basin residuals)	Metals, suspended solids, organics, radionuclides, biological, inorganics	Landfilling Disposal to sanitary sewer/WWTP Land application Surface discharge	RCRA/CERCLA State and local regulations RCRA, DOT NPDES (CWA), state and local DOH
Spent backwash filter-to-waste	Metals, organics, suspended solids, biological, radionuclides, inorganics	Recycle Surface discharge (pumping, disinfection, dechlorination) Disposal to sanitary sewer/WWTP	State and local DOH NPDES (CWA), state and local regulations State and local regulations
PRECIPITATIVE SOFTENING			
Calcium Carbonate and magnesium hydroxide sludge with raw water suspended solids and natural organic matter	Metals, suspended solids organics, unreacted lime, radionuclides	Landfilling Disposal to sanitary sewer/WWTP Land Application	RCRA/CERCLA, state and local regulations State and local regulations RCRA, state and local regulations, DOT
Spent backwash filter-to-waste	Metals, organics, suspended solids, biological, radionuclides, inorganics	Recycle Surface Discharge (pumping, disinfection, dechlorination) Disposal to sanitary sewer/WWTP	State and local DOH NPDES (CWA), state and local regulations State and local regulations
MEMBRANE SEPARATION			
Reject streams containing raw water suspended solids (microfiltration), raw water natural organics (nanofiltration, and brine (hyperfiltration, RO)	Metals, radionuclides, TDS, high molecular weight contaminants, nitrates	Surface discharge (pumping, etc.) Deep well injection Discharge to sanitary sewer/WWTP Radioactive storage	RCRA, NPDES, state and local regulations RCRA, NPDES, state and local regulations STate and local regulations RCRA, DOT, DOE

KEY : CCA=Clean Air Act; **CWA**= Clean Water Act; **CERCLA** = Comprehensive Environmental Response, Compensation and Liability Act; **DOE** = Department of Energy; **DOH** = Department of Health; **DOT** = Department of Transportation; **GAC** = Granular Activated Carbon; **RO** = Reverse Osmosis; **SOC** = Synthetic Organic Chemical: **TDS** = Total Dissolved

CONSTRUCTION, OPERATION AND MAINTENANCE ASPECT

Maintenance Scheduling

* Maintenance of each equipment is done as the recommendations of manufacturer.

* A History card is maintained for each equipment so that record is maintained for equipment performance and maintenance.

* Good housekeeping is an important aspect of plant operation.

Pumping Machinery

• To run the machinery in a way so as to have free fall from invert of sewer.

• Mostly 2 or 3 pump sets are out of order.

• Minimum one pump be operated during night hours so that sewers are empty in morning.

Screening Chamber & Wet Well

• Regular Cleaning

• Disposal of Screenings

• Washing of Bar Screens

• Washing sludge layer from walls using waterjet

• Desilting of wet well once a year.

Cleaning Chamber & Fine Screens

• Should be scoured minimum once in a week.

• Fine Screens should be kept clean of all obstructions. If the screen are of mat typ

its operation should be adjusted such that a mat is always on the screen.

Grit Channel

• (1W+18) grit channels for peak flow.

• Should be used one at a time, alternatively everyday.

• Should be cleaned everyday.

• Proper & efficient removal of silt in grit channel will improve the functioning treatment.

Proportional Weir

• It is provided to maintain uniform flow on upstream and downstream of gritchann

• Must be calibrated so as to show the quantity offlow.

• Flow be recorded every hour. In SBR Plants the flow recording graphs are recor in SCADA

Distribution Channel

• Must be cleaned every day.

Water Supply And Wastewater Engineering: Unit II: Water Treatment: Two Marks Questions And Answers

TWO MARK QUESTION AND ANSWERS

1. What are the main objectives of treating water?

(i) To remove colour, dissolved gases and murkiness of water

(ii) To remove objectionable tastes and odour.

(iii) To remove the disease producing micro-organism so that water is safe for drinking purposes

(iv) To remove hardness of water

(v) To make water suitable for industrial purposes such as brewing, dyeing and steam generation

2. Differentiate between unit operations and unit process in context of water treatment?

Unit Operations	Unit Process
Unit operations are primary treatment of water which uses **physical or mechanical forces** to create the desirable changes during water treatment	Unit processes are secondary treatment of water which uses chemicals or biological processes to get desirable changes during water treatment
Unit operations are mixing, agitating, aeration, absorption, membrane separation, distillation, sedimentation and filtration	Unit processes are oxidation, coagulation, chlorination and disinfection

Unit Operations

Unit operations are primary treatment of water which uses physical or mechanical forces to create the desirable changes

Unit operations are mixing, agitating, aeration, absorption, membrane separation, distillation, sedimentation and filtration

Unit Processi

Unit processes are secondary treatment of water which uses chemicals or biological processes to get desirable changes during water treatment

Unit processes es are oxidation, coagulation, chlorination disinfection

3. What are the various unit operations and unit processes used in the treatment of water?

Screening, Plain Sedimentation, Sedimentation with coagulation, Filtration, Disinfection, Aeration, Water Softening etc.

4. What are the factors influencing the settling of a particle?

• Horizontal flow velocity of water

• Viscosity of water

• Size and shape of particle

• Specific gravity of the particle

• Temperature of water

• Short circuiting of flow

• Scour velocity

5. State stokes equation for finding settling velocity of particles?

$$v_s = \frac{gd^2}{18v}(G-1)$$

V1 = settling velocity of particle

g = acceleration due to gravity

d = diameter of the particle

G = specific gravity of the particle

v = kinematic viscosity of particle

6. Differentiate between Plain Sedimentation and Sedimentation with coagulation

Plain Sedimentation: When water is detained in a tank, the large discrete suspende yot particles settle under gravity which is known as plain sedimentation. This require ($10 only a sedimentation tank.

Sedimentation with coagulation: The colloidal particles do not settle under gravity As such, coagulants such as alum, ferric chloride, chlorinated copperas etc are adde to water to make the colloidal particles to settle in a sedimentation tank. Thi process requires a flash mixer, flocculator and a sedimentation tank.

7. On what factors does the dose of coagulants depend?

Temperature, turbidity, pH, alkalinity, nature of coagulant, intensity and duratio br of mixing.

8. What are the common coagulants used in water treatment?

• Alum or aluminium sulphate

• Chlorinated copperas

• Iron salts - ferrous sulphate, ferric chloride, ferric sulphate no.

• Sodium aluminate

9. What is the significance of velocity gradient in flash mixer?

Velocity gradient (G) determines the mixing efficiency and power consumption a flash mixer. It also controls the floc formation in flocculators.

$$G = \left[\frac{P}{\mu V}\right]^{\frac{1}{2}}$$

10. Define: Detention time and surface over flow rate for a sedimentation tank?

Detention time is theoretical time taken by a particle of water to pass betwee entry and exit of the settling tank. t = volume of tank / rate of flow

Surface loading rate or surface over flow rate

The quantity of water passing per hour per unit horizontal area is known as the ove flow rate or surface loading.

SOR or SLR = Discharge/Surface Area

11. What is coagulation?

The process of addition and mixing of chemicals (coagulants) in water to aid in th settling of colloidal and fine suspended particles is called coagulation.

12. Define Flocculation.

The process of floc formation by the aggregation of chemical precipitate and colloid is known as flocculation.

13. Define filtration. What are the different types of filters?

The process of passing the water through the beds of granular materials is known a filtration.

Types: Slow sand filters, Rapid sand filters, Pressure filters etc

14. What is schmutzdecke layer or dirty skin?

After few weeks of commissioning the sand filters, a layer of algae, bacteria protozoa, suspended particles and partly decomposed organic matter is formed o the surface of sand, which is called the dirty skin or schmutzdecke layer. This laye helps in further absorbing organic matter from water.

15. What is the theory of filtration?

• Mechanical straining

• Sedimentation

• Biological metabolism

• Electrolytic changes

16. List out advantages of rapid sand filter?

• High filtration rate 3000 to 6000 litres/m2/hr

• Occupies less area

• Less initial cost

• Donoldo boilggs

17. What are the operational problems in sand filters?

Formation of mud balls: Mud from atmosphere may accumulate on the sand surface. It is broken by mechanical rakes or by washing with water under pressure.

Cracking or clogging of filters: The fine sand in the top layers may shrink causing ow shrinkage cracks.

Air binding: The dissolved air and gases from water, occupy the void space of filter media. This can be controlled by preventing any algal growth on filters and by Tavo preventing super-saturation of water.

18. What are the advantages and disadvantages of pressure filters?

Advantages: Compact, automatic operation, requires small area for installation, very high rate of filtration 6000 to 15000 litres per hour per square meter.

Disadvantages: Treatment cost is high, efficiency of bacteria removal is low.

19. Differentiate between sterilisation and disinfection?

Sterilisation	Disinfection
Boiling of water to destroy all the microorganisms present in water	Using chemicals to destroy the disease causing microorganisms or pathogens. Disinfectants used are chlorine, ozone, UV, potassium permanganate etc.
Cost is more	Cost is comparatively less.
Can be used for small plants	Used in large water treatment facilities

20. List the different methods of disinfection. Enumerate the mechanism o disinfection process?

Mechanism of disinfection may be chemical or physical which are tabulated below

Physical: Boiling, Ultra-violet radiation.

Chemical: Chlorination, Bromine and Iodine, Potassium permanganate, Ozon Excess Lime.

21. What is break point chlorination?

The chlorine added to water is utilized in the oxidation of organic matter and killin of bacteria. It reacts with the ammonia to form chloramines. During the initi phase of chorine addition, the residual chlorine or free chlorine will be less than the applied chlorine. But further dosage of cholorine beyond a certain value. Will equally appear as free residual chlorine. This dosage of chlorine is called as break point chlorination. Residual chlorine limit is 0.2 to 0.3 mg/l

22. What are the advantages of chlorine as disinfectant?

• Kills germs and disease causing bacteria effectively

• Cheap and easily available

• Can be stored for long periods

• Prevention of algal growths

• Taste and odour control

23. What are the tests to be done to find the residual chlorine in water?

• Orthotolidine test

• D.P.D test

• Chlorotex test

• Starch Iodide test

24. How to manage the residue in water treatment plant?

Land filling, horticulture use, disposal to waste water injection, regeneration of coagulants, incineration.

25. Define aeration.

Aeration is the process of gas transfer between water and air.

26. State the objectives of aeration process in water treatment?

• To remove dissolved gases, such as carbon dioxide, hydrogen sulfide

• To remove iron and manganese.

• To remove taste and odour.

• To increase the DO of water.

27. Mention the types of aerators used in water treatment?

(a) Spray nozzles

(b) Cascade aerators

(c) Air diffusers

(d) Trickling bed aerators

28. List the pollutants that get removed in an aerator?

Carbon dioxide, Hydrogen sulfide (rotten-egg odour), Methane (flammable), Iron (stains clothes and fixtures), Manganese (black stains), Volatile organic chemicals, taste and odour

29. How do you remove iron and manganese from water?

List out the unit process applied to remove iron and manganese from water?

Iron and manganese from water can be removed by the following methods:

(a) Aeration

(b) Manganeze Zeolite

Addition of lime, chlorine and potassium permanganate

30. Define hardness of water? What are the types of hardness present in water?

It is a property of water, which prevents the lathering of soap. Hardness is of two types: Temporary Hardness and Permanent Hardness

31. Differentiate between Temporary Hardness and Permanent Hardness?

Temporary Hardness

This is due to the presence of carbonate and bicarbonate of Calcium and

This is also called as Carbonate This is also called as Non-Carbonate Hardness

It can be removed easily by boiling and adding lime

Permanent Hardness

This is due to the presence of sulphates, chlorides and nitrates of Calcium and Magnesium

This is also called as Non- Carbonate Hardness

Its removal requires special treatment like zeolite or lime-soda process.

32. Describe about the term water softening?

Reduction or removal of hardness from water is known as water softening. Temporary hardness is removed by boiling and addition of lime.

Permanent hardness is removed by: Lime-soda process, base exchange or zeolite process, and demineralization process.

33. List out any four effects of hardness in water?

• Causes more consumption of soap in laundry work.

• Affects dyeing of textiles

• Causes difficulties in paper, canning, ice and rayon industry

• Causes choking and clogging of pipes

• Causes scaling in boilers and heaters

• Makes food tasteless, tough or rubbery

34. What are the methods of removing hardness?

• Boiling

• Addition of lime.

• Lime-soda process

•Base exchange or Zeolite process

35. What is Zeolite process?

Silicates of aluminium and sodium compounds, which exchange calcium and magnesium ions for sodium ions is known as zeolite process. Zeolites are used in the water softening process to remove permanent hardness from water.

36. What are the advantages of Zeolite process?

No sludge is formed, hence problem of sludge disposal does not arise.

It can be operated easily and no skilled supervision is required.

Hardness of water reduces to zero and hence used for boiler and textile industries. Economical process

37. What is demineralization?

It is the removal or reduction of minerals in water to make it suitable for industrial and domestic purposes. It involves cation exchange process followed by anion exchange process.

38. How do you regenerate softener?

Water softeners can be regenerated by treating with 5-10% solution chloride (Brine solution)

$CaZ + 2NaCl = Na_2Z + CaCl_2$

$Mg + 2NaCl = Na_2Z + MgCl_2$

39. Define Fluoridation?

If the fluoride concentration in water is less than 1 mg/l, excess fluoride is added to water which is called as fluoridation.

40. Name the methods of deflouridation?

• Prashanthi technique using adsorption by activated alumina

• Ion exchange adsorption method

• Nalgonda technique

• Reverse osmosis process

41. What is the maximum permissible limit of fluoride in drinking water?

Acceptable limit of flouride in drinking water is 1 mg/l

42. Define the term fluorosis.

Disease caused by intake of excess fluoride affecting the bone and teeth is known as fluorosis.

43. Water Supply and Waste Water Engineering

Dental fluorosis: discolouration and pitting of teeth

Skeletal fluorosis: severe bone deformation

Non-skeletal fluorosis: gastrointestinal problems, neurological problems

44. Distinguish between physical a dsorption and chemical adsorption?

Physical Adsorption	Chemical Adsorption
The forces operating in the physical adsorption are weak	The forces operating in the chemical adsorption are similar to those of a chemical bond.
Takes place at low temperature and decreases with increase in temperature	Takes place at high temperature
Heat of adsorption is low	Heat of adsorption is high

45. Write down the principle of desalination of water?

Desalination is the process of removing dissolved salts from water, thus producin fresh water from seawater or brackish water. Salts are present in water as Na+ catio and Cl- anion. These ions are separated either by oppositely charged electrodes o ion selective membranes.

46. Mention any four methods of desalination process?

a. Evaporation and Distillation

b. Electrodialysis

c. Reverse osmosis

d. Freezing process

e. Solar distillation method

47. What is Reverse Osmosis?

The natural osmotic pressure is opposed by exerting an external pressure on t side containing the salt solution which forces pure water from the salt solution [S10 move across a semi-permeable membrane towards the side containing water. Th process is called as reverse osmosis.

UNIT - III

WATER STORAGE AND DISTRIBUTION

REQUIREMENTS OF A GOOD DISTRIBUTION SYSTEM

(i) To supply water at sufficient pressure head.

(ii) To supply requisite quantity of water for fire fighting.

(iii) Cheap with least capital (construction) cost. The cost of installation of distribution system is about 70% cost of water supply projects.

(iv) Simple, easy operation and repair. RMO cost and troubles should be minimum.

(v) Safe against future pollution of water. Water lines should be laid away from drainage and sewerage lines.

(vi) Safe and should not cause failure of pipelines by bursting.

(vii) Water should be available even during breakdown periods.

(viii) Water-tight and leakage losses should be minimum.

(ix) No obstruction of traffic during repairs.

STORAGE AND BALANCING RESERVOIRS

• Storage Resevoirs - store the treated water until it is pumped into the service reservoir or distribution reservoirs.

The capacity of storage reservoirs should be 14 to 16 hours of average daily flow.

• Distribution Reservoirs - provide storage to meet the widely fluctuating demands, for fire-fighting and during emergencies.

Distribution Reservoirs serve the following purposes:

(i) They absorb the hourly variations in demand.

(ii) The pumps can be run at constant rate.

(iii) Reduction in pipe sizes, pumps and treatment units (economical)

(iv) They serve as storage for emergencies such as fire/ failure of pumps/ bursting mains etc.

(v) They maintain desired pressure even in remote areas.

(vi) Operation of distribution system becomes very easy.

Types of Storage and Distribution Reservoird:

1. Surface Reservoirs

2. Elevated Reservoirs

3. Stand Pipes

1. Surface Reservoirs (Ground Reservoirs)

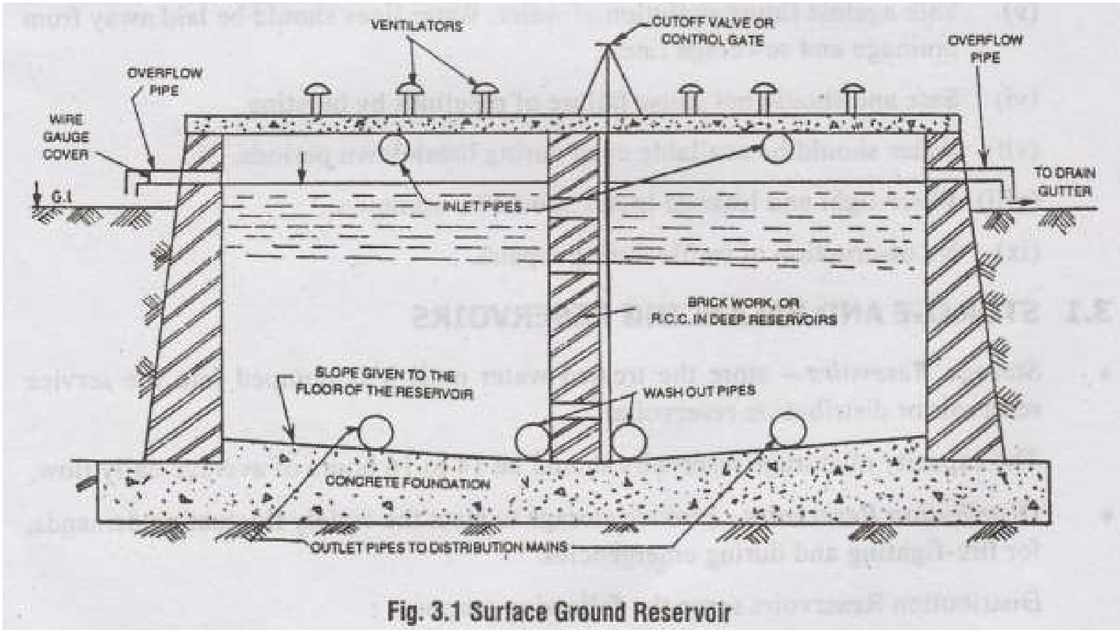
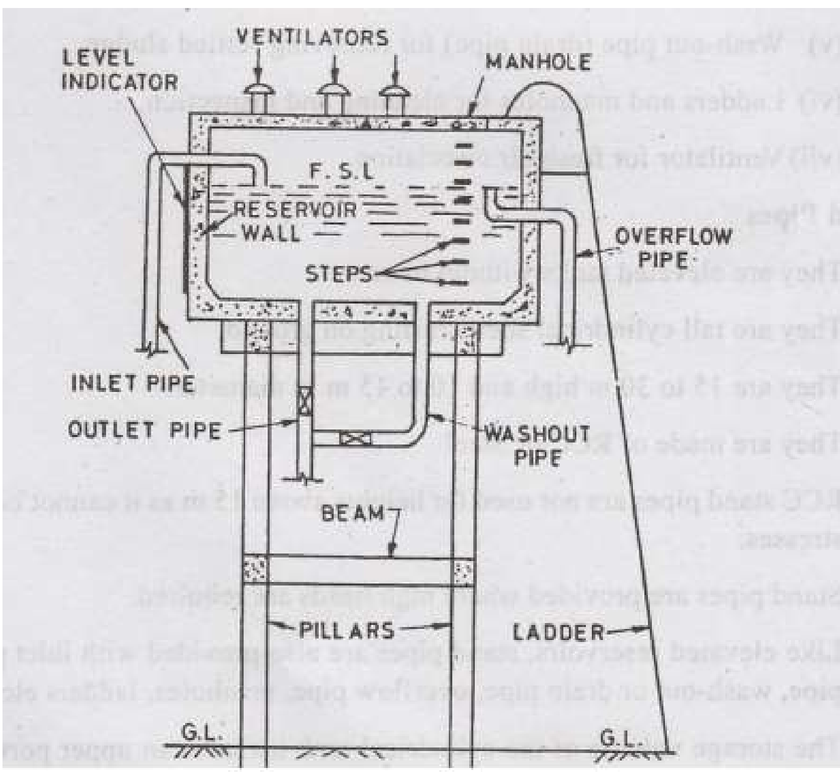


Fig. 3.1 Surface Ground Reservoir

2. Elevated Reservoirs (Overhead Tanks)



3. Stand Pipes

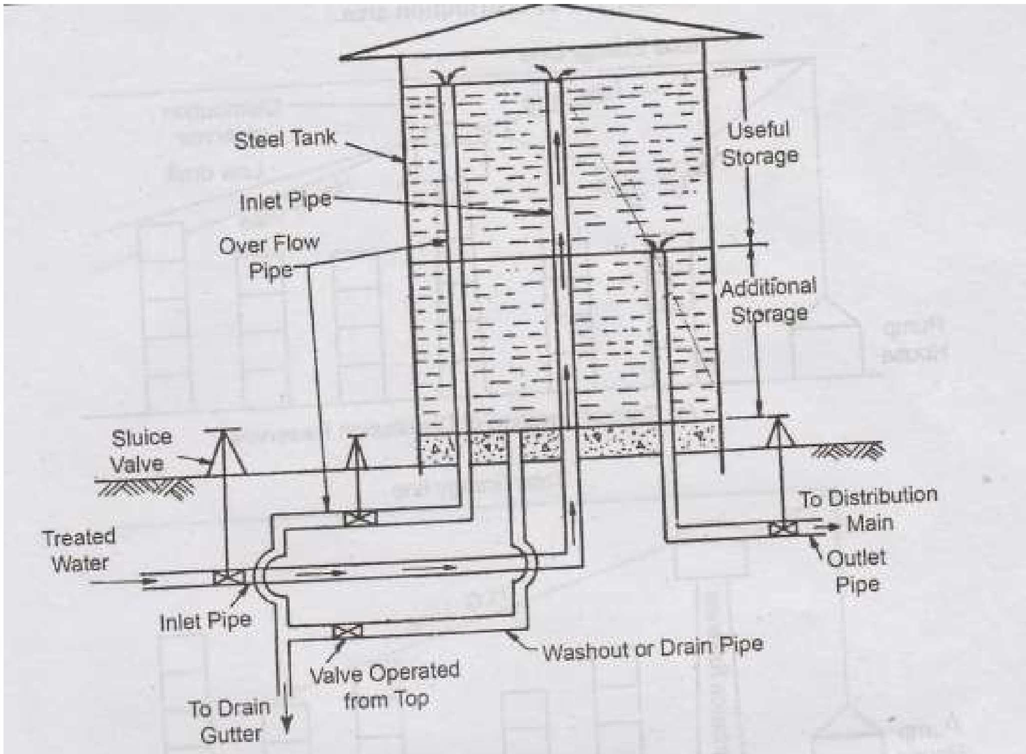


Fig. 3.3 Stand Pipes

Location of the Distribution Reservoirs

Following points are considered in deciding the location of distribution reservoir :

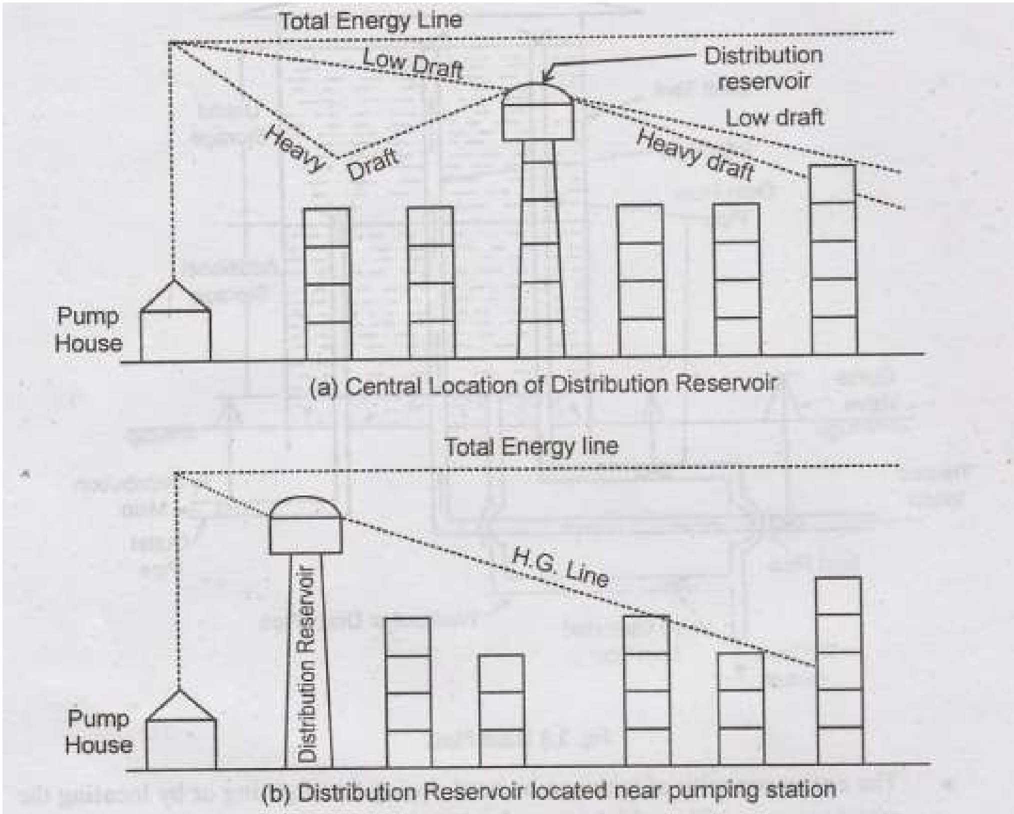


Fig. 3.4 Effect of location of Distribution Rservoir

STORAGE CAPACITY OF DISTRIBUTION RESERVOIRS

The total storage capacity of a distribution reservoir is the total of

1. Balancing storage (or equalising or operating storage)

2. Breakdown storage.

3. Fire storage

1. Balancing or Equalising Storage:

• The primary function of a distribution reservoir is to meet the fluctuating demand.

• The quantity of water required to be stored in the reservoir for balancing the variable demand is called balancing storage of the distribution reservoir.

• This can be found by following methods :

(a) Hydrograph Method.

(b) Mass curve Method.

(c) Analytical Methods.

(a) Hydrograph Method :

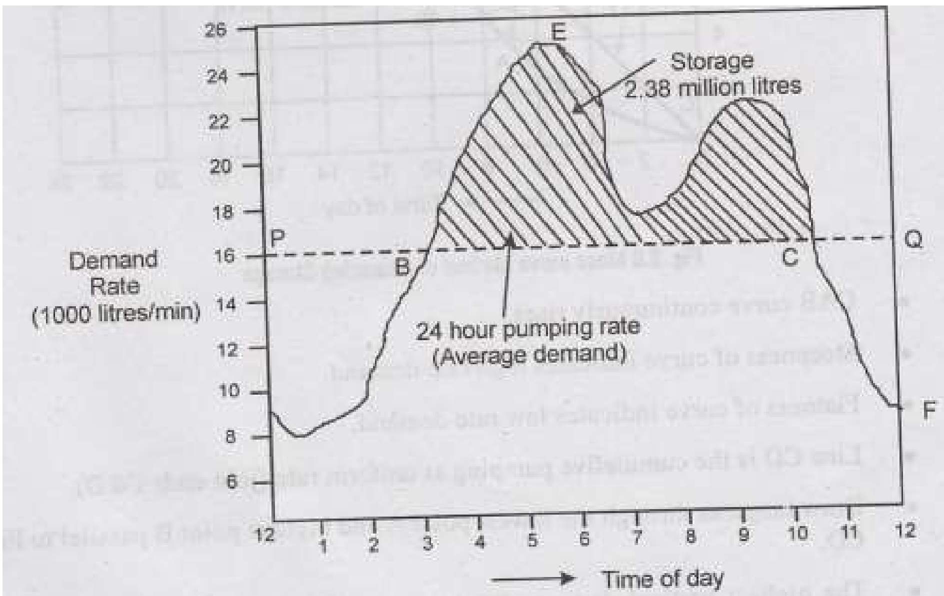
• The water demand is not constant and varies hourly.

• The demand is more during peak hours in the morning and evening. A

• A hydrograph of hourly demand for maximum day is shown in figure 3.5.

• The pumping rate i.e. mean of hourly demand is shown by line PQ.

• The storage is obtained by determining the shaded area between curve BE and line PQ.



(b) Mass Curve Method:

A mass curve is the cumulative demand curve which is obtained by continuously adding the houly demands of the maximum day and plotting against time.

Figure 3.6 shows the mass demand curve CAB plotting it against hours of maximum day.

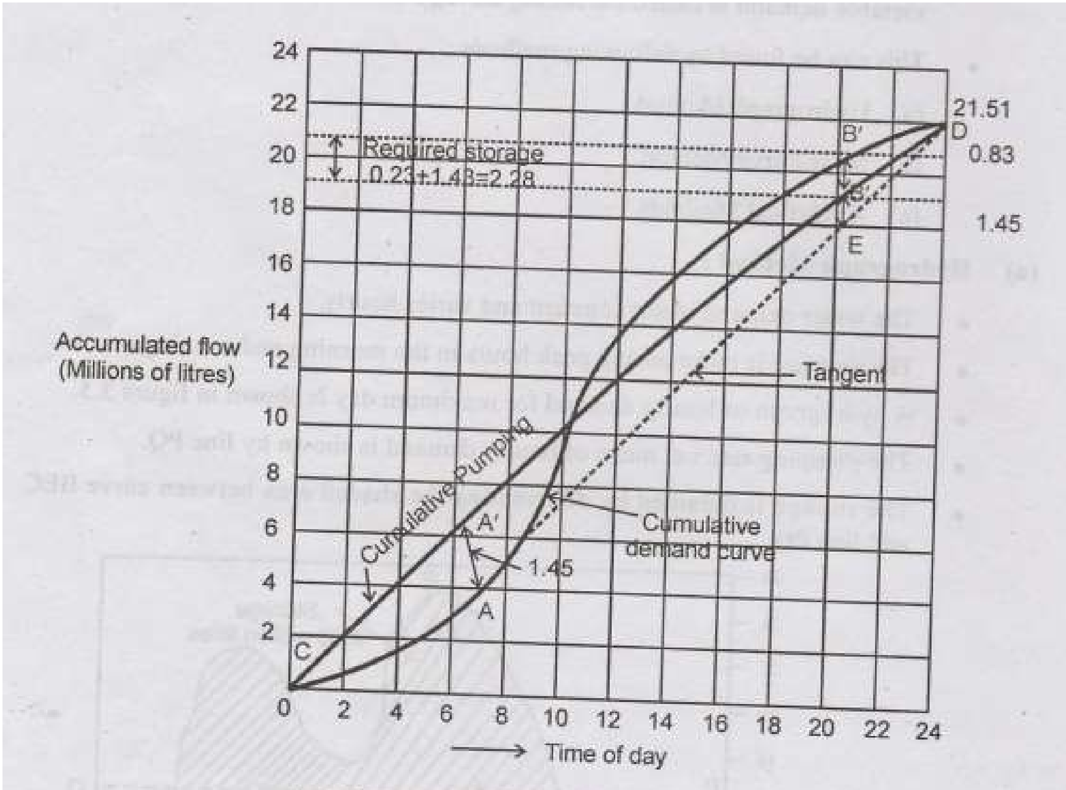


Fig. 3.6 Mass curve Method of Balancing Storage

(c) Analytical Method

The cumulative hourly demand and cumulative hourly supplies are tabulated for 24 hrs. The summation of maximum excess demand and the maximum excess supply gives the balancing storage

2. Breakdown storage (Emergency storage)

• It is the storage for emergencies due to pump failure, power failure and during repair works.

• It is difficult to determine this storage as it depends upon the frequency and extent of failures.

• Generally, 25% of total storage capacity of reservoir or about 11⁄2 to 2 times average hourly supply may be considered as breakdown storage.

3. Fire Storage:

• This storage is required for fire fighting, which depends on the chances of fire and duration of fire.

• The National Board of Fire Under Writers (America) recommends that the reserve should supply water for 10 hours for fire fighting in communities of 6000 people and for 8, 6 and 4 hours in places with 4000, 2000 and 1000 people respectively.

• For 10 hours of fire fighting per day, the volume of water required to be stored should be 2 million litres.

Fire reserve is determined from the formula :

R = [F-P] T

P = reserve fire pumping capacity, litres/min

T= duration of fire, minutes.

McDonand has suggested the following expression

$$R = aD + bD + \frac{10}{24}(D + F - P)$$

Where,

R = total storage capacity (million litres)

D= average domestic demand for maximum month (MLD)

F = fire demand (MLD)

P = Pump capacity (MLD)

a,b = Coefficients; 0.2 and 0.1 respectively.

Problem 5.1:

A town with a population of one lakh is to be supplied with water daily at 200 litres per head. The variation in demand is as follows

6 to 9 am	–	40% of total
9 am to 12 noon	–	10% of total
12 to 3 pm	–	10% of total
3 to 6 pm	–	15% of total
6 to 9 pm	–	25% of total

Determine the capacity of service reservoir assuming pumping at uniform rate and the period of pumping to be from 6 am to 6 pm.

Neglect fire demand.

Solution:

Total daily requirement = 1,00,000 x 200 litres = 2 x 107 litres = 20 ML

(a) Analytical Solution

Period	Hours	Rate of demand	Demand in ML	Cumulative demand in ML.	Supply at 5 ML per 3 hr	Cumulative supply ML	Excess demand +ve values	Excess supply +ve values
6 am – 9 am	3	40% of 20 ML	8	8	5	5	3	–
9 am–12 noon	3	10% of 20 ML	2	10	5	10	–	–
12 noon–3 pm	3	10% of 20 ML	2	12	5	15	–	3
3 pm – 6 pm	3	15% of 20 ML	3	15	5	20	–	5
6 pm – 9 pm	3	25% of 20 ML	5	20	Nil	20	–	–
		$\Sigma = 100\%$	20 ML				Max =3	Max =5

Max. excess demand = 3 ML

Max. excess supply = 5 ML

Total storage = 3+5 = 8ML

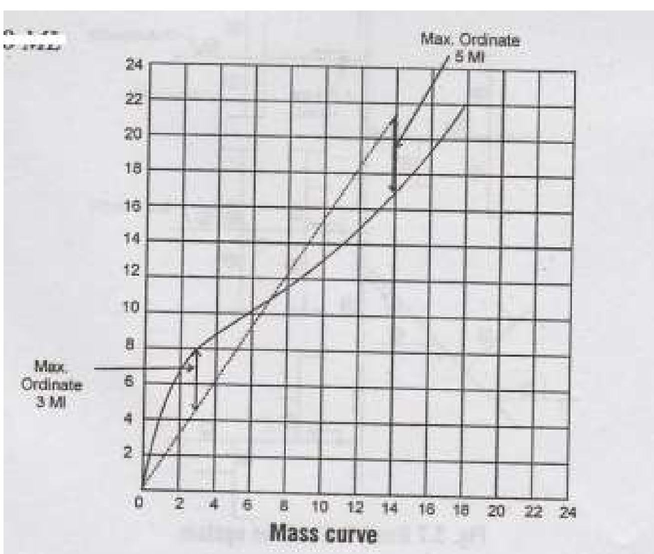
(b) Mass curve method

Graph is plotted between time and cumulative demand.

Pumping rate = 20 ML /12 hr = 1.667 ML | hr

The supply curve is drawn with slope as 1.667 ML/hr. Maximum ordinates are found between supply and demand lines.

Storage = 3 ML + 5 ML = 8 ML



DISTRIBUTION SYSTEM - LAYOUT

The different types of distribution networks are:

1. Dead end system

2. Grid iron system

3. Ring system (circular)

4. Radial system

1. Dead-end system (Tree system)

• There is one main supply pipe, from which a number of submain pipes take off at right angles.

• Each submain divides into several branch pipes (Laterals)

• From lateral, service connection are given to consumers.

• Used for older towns with irregular expansion, without properly planned roads.

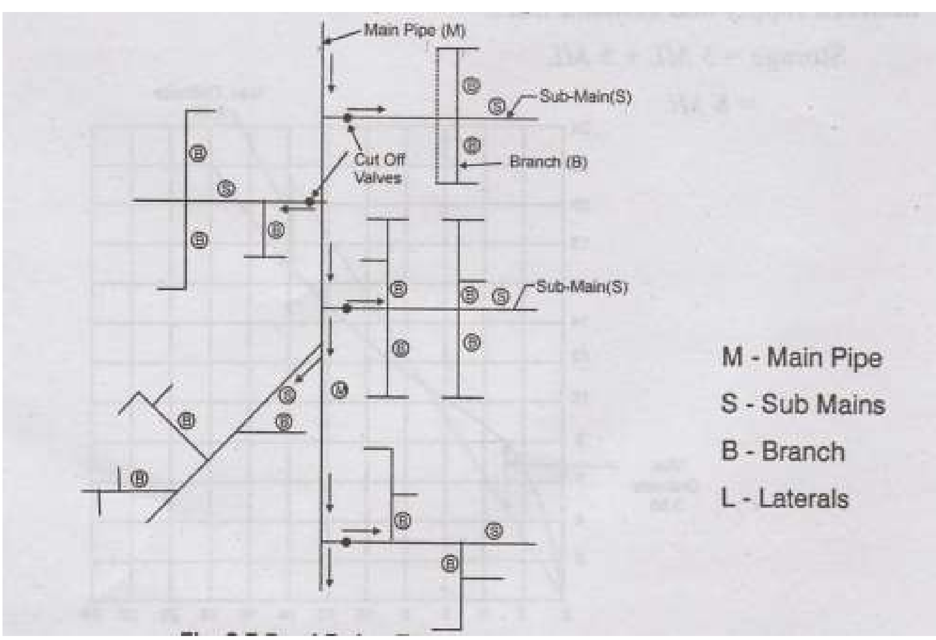
• Water pipes are randomly laid which leads to formation of number of dead ends.

• As there are no cross connections between the branches, submains and laterals etc. sediment accumulation and water stagnation occurs in the dead ends.

Advantages:

• Distribution network can be easily solved. Discharges and Pressures at different points can be easily and accurately calculated.

• Requires lesser number of cut-off valves (sluice valves)



Disadvantages:

• Damage or repair in any pipeline completely stops water supply to that area. Greater inconvenience to consumers.

• Numerous dead ends. Stagnation of water leads to degradation of water quality.

• Periodic removal of stale water at dead ends is required by providing scour valves. Greater wastage of treated water.

• Supply is only in one direction. Supplies for fire fighting cannot be increased by diverting supplies from other side.

2. Grid-Iron system / Interlaced / Reticulation system

• Mains, sub-mains and branches are all inter-connected with each other. In a well-planned city/town, roads are properly developed and the pipelines can follow a grid-iron pattern.

Advantages:

• Since water reaches different places from different routes, the discharge, friction loss, and pipe size are reduced.

• During repairs very small area is affected. Some supply will still reach the area from other route.

• Due to the inter-connections, dead ends are eliminated. Water remains in continuous circulation, which prevents stagnation, pollution and sediment deposits.

• During fire, more water can be diverted towards the affected area by closing the cut off valves.

Disadvantages:

• Requires more pipe length and large number of sluice valves (cut off valves).

• Costlier construction

• Design is difficult and costlier. Calculations for determing the pipe size, discharge, velocities and pressures are tedious and may require design experts and computers.

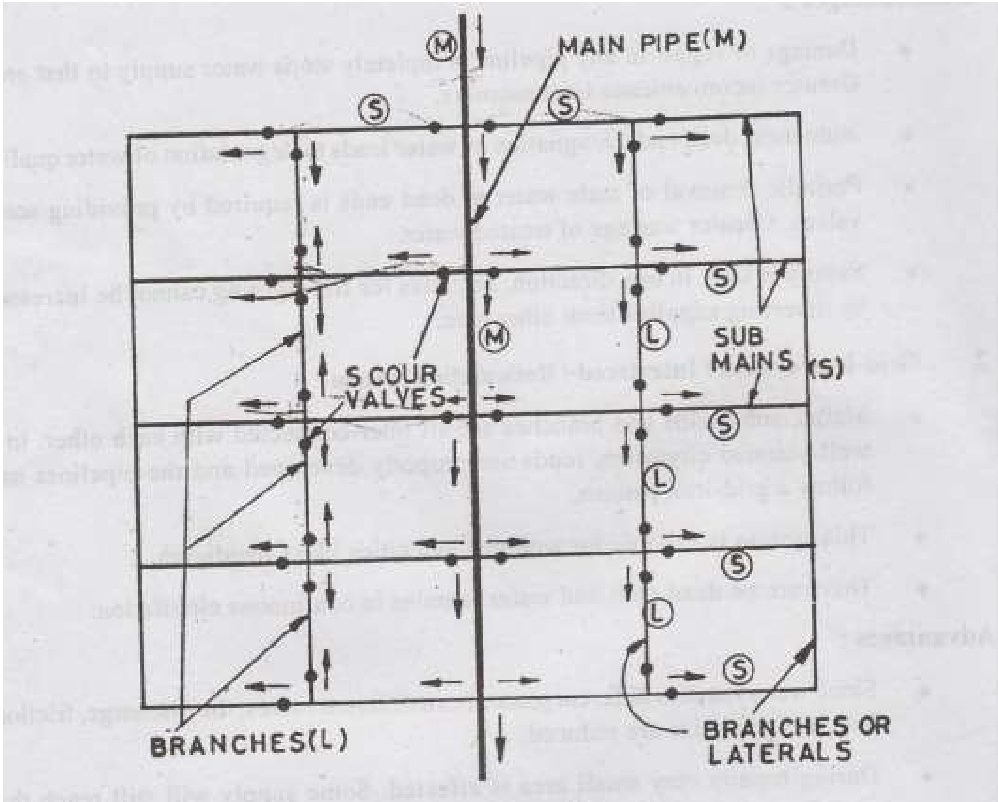


Fig. 3.8 Grid - Iron system

3. Ring System/ Circular system

• A closed ring either circular or rectangular, of the main pipe is formed around the area to be served. The distribution area is divided into rectangular or circular gniadlo blocks. The main pipes are laid on the periphery of these blocks.

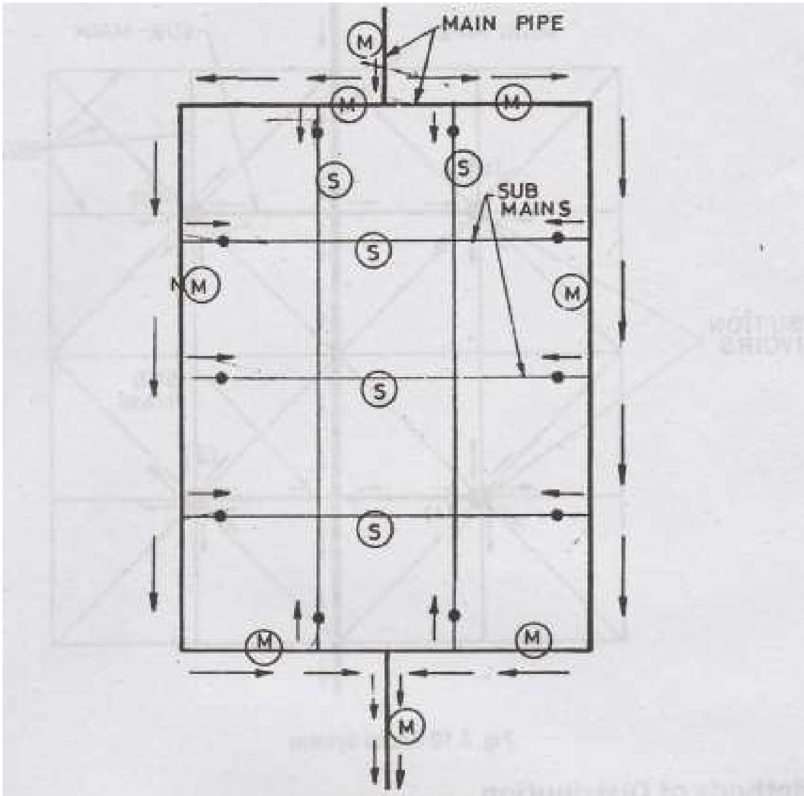


Fig. 3.9 Ring System

4. Radial system (Reverse of circular)

• Suitable for city or town having radial roads emerging from different

• The distribution reservoirs are placed at these centres.

• Water from the water mains is pumped into the distribution reservoirs placed at different centres. Water is then supplied through radially laid distribution pipes.

• This method ensures high pressures and efficient water distribution.

• The calculations for design of pipe sizes are also simple.

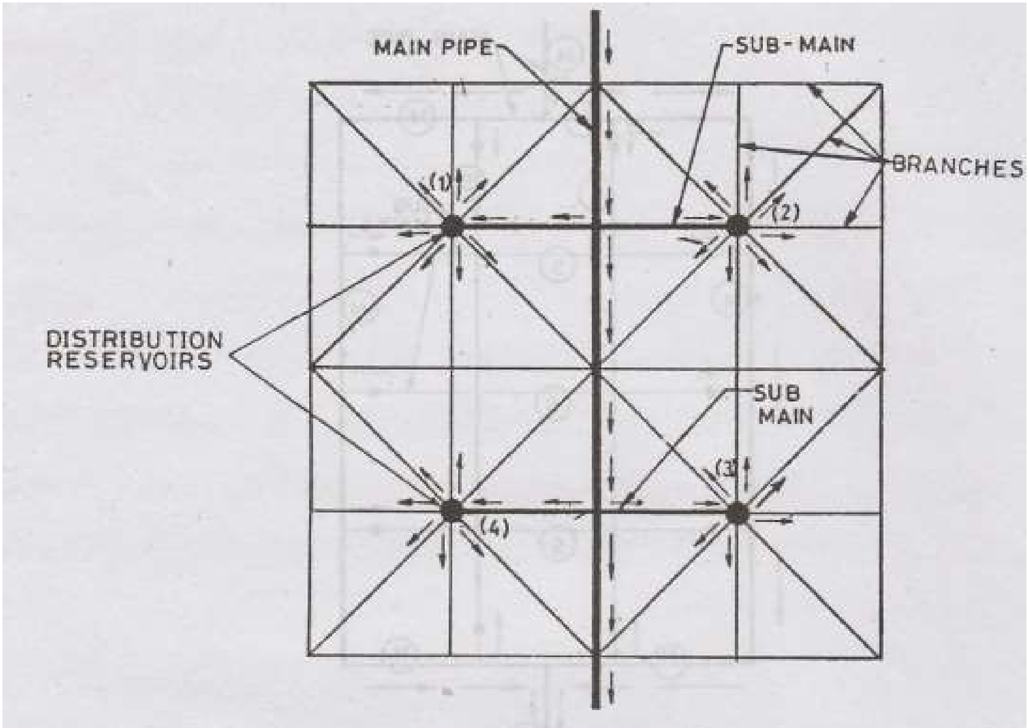


Fig. 3.10 Radial System

1. Gravitational system

• This system is adopted when the source (lakes or reservoirs) are at high leve and the distribution area or consumers are at low level.

• Water flows from high level to low level under gravity.

• Economical and reliable system, since no pumping is required.

• Economical and reliable system, since no pumping is required..

• However, sufficient head should be available to maintain adequate pressure a the consumer's end after allowing frictional losses in pipes.

• Suitable for cities located at the foothills.

Example :Mumbai city is supplied from lakes situated in the hills.

• Leakage and wastages are minimum.

• Size of pipes is reduced for a given discharge.

• Pumping is required only during fires to increase pressure.

2. Pumping System (Pumping without storage system)

• Treated water (without storage) is directly pumped into the distribution mains.

• High lift pumps are required to be operated at variable speeds to meet the water demand.

• Continuous supervision is required at pumping station.

• During power failures, there will be complete stoppage of supply.

• During fires, large volume of water can be forced at high pressure. But, in case there is a fire during power breakdown, it will be a disaster.

3. Combined Gravity and Pumping System

• The treated water is pumped at a constant rate and stored into an elevated disribution reservoir.

• From the elevated reservoir, water is distributed to the consumers, by gravity.

• The system is also called as pumping with storage system; which combines gravity flow and pumping.

• The excess water during low demands is stored in the reservoir and is supplied during high demand periods.

• The pumps are operted at constant speeds at their rated capacities which increases efficiency and reduces wear and tear. Supervision is also not required.

HYDRAULICS OF PIPE LINES

(i) The bed of pressure conduits should be as far as possible near HGL (Hydraulic M (ii) atibo gradient line).

Otherwise the increased pressure in pipes necessitates thicker and stronger pipes which will increase the cost.

(ii) Hydraulic Gradient Line should generate sufficient velocities. The velocity should be non silting / non-scouring. (0.9 m/s to 1.5 m/s)

(iii) Structural stability

(iv) Economical construction

(v) Head loss due to pipe friction.

(vi) Loss due to changes in flow geometry i.e., change in pipe size, bends, valves etc.

Problem 3.2:

In a water supply system to be designed for serving a population of 4 lakhs, the storage reservoir is situated at 8 km away from city and the loss of head from source to city is 16 meters. Calculate the size of supply main by using Weisbach formula as well as by using Hazen’s formula assuming a maximum daily demand of 200 litres per day per person and half of the daily supply to be pumped in 8 hours. Assume coefficient of friction for the pipe material as 0.012 in Weisbach formula and CH = 130 in Hazen’s formula

Solution:

Maximum daily per capita demand = 200 lpcd

Population = 4,00,000

Maximum daily water demand = Population x per capita demand

= 4,00,000 × 200 lpcd

= 80 × 106 1/d

= 80 MLD

Maximum water demand for which supply main is to be designed

80×24/2 × 1/8 = 80×12/8 MLD=120 MLD

(Since half the daily supply is pumped in 8 hrs)

Q=120 MLD: = 120×106 /103 × 24 × 60 × 60 m3/s=1.39m3/s

Now, Q = 1.39 m3/s, L = 8 km = 8000 m, HL = 16m

(a) Using Darcy-Weisbach formula

$$= \frac{fL}{2gD} \times \frac{16Q^2}{\pi^2 d^2} = \frac{8fLQ^2}{g\pi^2 d^5} \qquad \left[A = \frac{\pi}{4}d^2\right]$$

$$16 = \frac{8\times(0.012)(8000)(1.39)^2}{9.81\times(3.14)^2\, d^5}$$

Solving, $d^5 = 0.957$; $\quad d = 1.092$ m $(\approx 1.25$ m$)$

Use the nearest standard available pipe diameter (i.e. 1.25 metre diameter)

(b) Using Hazen-William’s formula

$V = 0.85\, C_H R^{0.63} S^{0.54}$

Where $C_H = 120$

$$R = \frac{d}{4}$$

$$V = \frac{Q}{A} = \frac{1.39}{\frac{\pi}{4} d^2}$$

$$\frac{1.39}{\frac{\pi}{4} d^2} = 0.85 \times 130 \left(\frac{d}{4}\right)^{0.63} \left(\frac{H_L}{L}\right)^{0.54}$$

$$= 0.85 \times 130 \frac{d^{0.63}}{2.4} \left(\frac{16}{8000}\right)^{0.54}$$

$$\frac{177}{d^2} = 46 d^{0.63} \frac{1}{28.7}$$

$d^{2.63} = 1.104$

$d = 1.038$ m $\quad \simeq 1.25$m

Use the nearest standard available pipe diameter (1.25 metre diameter)

PIPE FITTINGS

Requirements of jointing material

(i) Imperviousness

(ii) Elasticity

(iii) Strength

(iv) Durability

(v) Adhesiveness

(vi) Workability

(vii) Economy

(viii) Availability

Different types of joints are:

(i) Spigot and socket joint

(ii) Flanged joint

(iii) Mechanical joint or Dresser coupling

(iv) Flexible joint

(v) Expansion joint

(vi) Simplex joint

Appurtenances in Distribution System

The following appurtenances are required for the efficient functioning of the distribution network.

1. Valves

2. Fire hydrants

3. Water Meters

4. Water Taps

5. Stop Cocks

6. Pipe Bends etc.

ANALYSIS OF DISTRIBUTION SYSTEMS

Conditions to be satisfied in pipe networks:

• The Algebraic sum of pressure drops around a closed loop must be zero. (i.e. no discountinuity in pressure)

• The flow entering a junction must be equal to the flow leaving the same junction. i.e. law of continuity must be satisfied.

Pipe networks are solved by the following methods:

(1) Hardy - Cross Method

(2) Equivalent Pipe Method

1. HARDY-CROSS METHOD

• This method is based on the principle of "Law of Continuity". i.e. at any junction, Inflow = Outflow

• The flow in each pipe is assumed.

• A correction to the assumed flow is computed successively for each pipe loop in the network, until the correcton is reduced to an acceptable magnitude.

If Q = assumed flow, Q = actual flow, then correction A is given by sub divendr

$\Delta = Q - Q$

$$Q = Q_a + \Delta$$

Head loss in the pipe is given by

$$H_L = K.Q^x$$

$$= K\,(Q_a + \Delta)^x$$

$$= K\,[Q_a^{\,x} + xQ_a^{\,x-1}\,\Delta + \text{....Negligible terms containing higher powers of } \Delta]$$

$$= K\,[Q_a^{\,x} + xQ_a^{\,x-1}\,\Delta]$$

$$\Sigma K\,[Q_a^{\,x} + xQ_a^{\,x-1}\,\Delta] = 0$$

$$\Sigma K Q_a^{\,x} = -\Sigma Kx\,Q_a^{\,x-1}.\,\Delta$$

Δ is same for all the pipes of considered loop.

Hence, Δ is taken out of summation

$$\Sigma KQa^x = -\,\Delta\,\Sigma Kx\,Qa^{x-1}$$

$$\Delta = \frac{-\Sigma KQ_a^x}{\Sigma KxQ_a^{x-1}} = \frac{-\Sigma K\cdot Q_a^x}{\Sigma\left|x\cdot KQ_a^{x-1}\right|} \qquad \text{........... (1)}$$

$$\Delta = \frac{-\Sigma H_L}{x\Sigma\left|\dfrac{H_L}{Q_a}\right|} \qquad \left[\because H_L = KQ^x\right] \qquad \text{........... (2)}$$

Where H_L = head loss for the assumed flow Q_a.

x is constant ; $x = 1.85$ (for Hazen-William's formula)

$x = 2$ (for Darcy-Weisbach formula)

• Algebraic sum of head losses in various pipes in closed loop is computed with assumed flow.

• Correction A is found for each loop

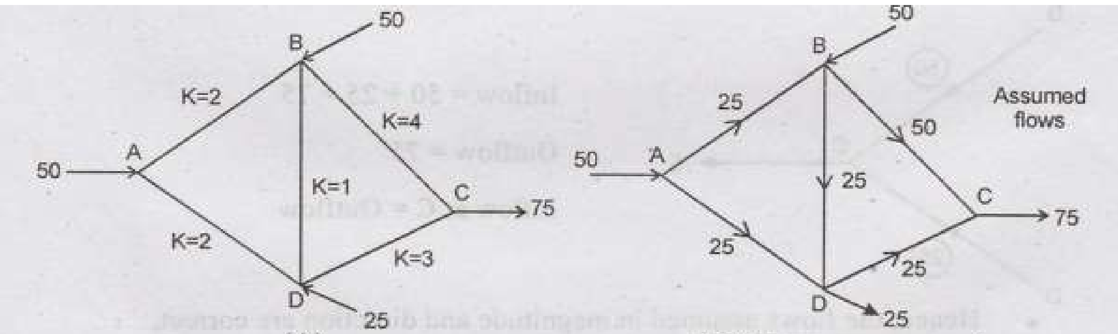
• Assumed flows in each pipe are corrected.

• Pipes common to two loops will receive both corrections with due attention to sign.

Problem 3.3:

Determine the distribution of flow in the pipe network. The Head loss H1 may be assumed as KQ”. The flow is turbulent and pipes are rough. The Value of K for each pipe is shown in figure. Use Hardy Cross method.

Solution:

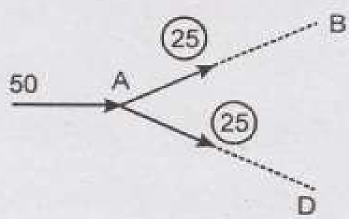


(A) (B) Flows are assumed

The Magnitude and directions of possible flows in each pipe are assumed based o the Law of continuity at junction.

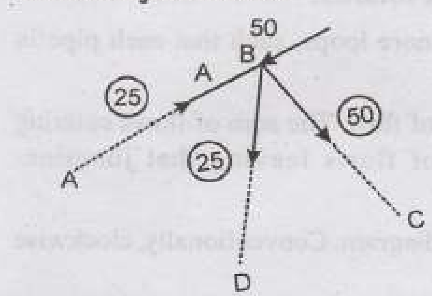
At any junction ; Inflow = Outflow.

Consider junction A



Inflow is 50 at A; as it branches out into tw pipes; the flow in each pipe AB & AD i assumed as 25.

Consider junction B

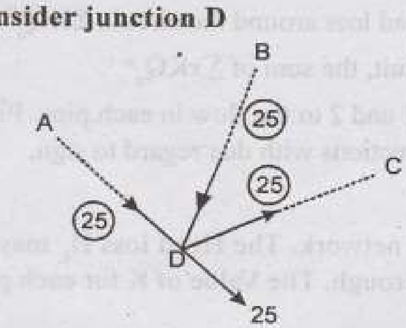


Inflow at B = 50 + 25 = 75

The flow in BC and BD are assumed as : and 25; direction away from junction.

Hence, Out flow = 50+25 = 75.

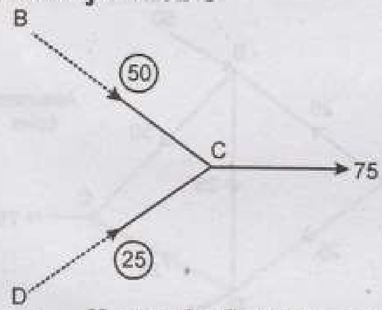
Consider junction D



Inflow at D = 25 + 25 = 50

Since outflow should be 50, flow in DC assumed as 25.

Consider junction C



Inflow = 50 + 25 = 75

Outflow = 75

Inflow at C = Outflow

- Hence, the flows assumed in magnitude and direction are correct.
- The network is divided into two loops; loop ABDA and loop BCDB. These loops are analysed by Hardy-Cross Method in Table.
- The flow in the clockwise direction is considered positive and anticlockwise direction is negative.

Formula for correction

$$\Delta = \frac{-\Sigma H_L}{x \Sigma \left| \frac{H_L}{Q_a} \right|}$$

Assume $x = 2$ (Darcy-Weisbach formula)

The head loss in each pipe is calculated

$$H_L = KQ^n$$

Assume $n = 2$ [Manning's formula or Darcy Weisbach formula; for turbulent flow-rough pipes]

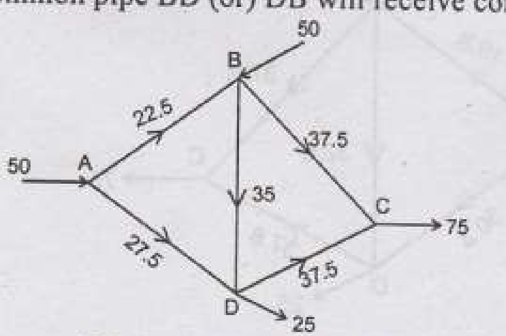
$$\therefore H_L = KQ^2$$

Hardy Cross Procedure for 1st correction

Pipe	Assumed flow	K(given)	$H_L = KQ_a^2$	$\left\lvert\frac{H_L}{Qa}\right\rvert$	Corrected Q after first correction $Q_{a1} = Q_a + \Delta_1$ (*l*/s)
1	2	3	4	5	6
For loop ABDA (loop 1)					
AB	25	2	1250	50	25–2.5 =+ 22.5
BD (Common pipe)	25	1	625	25	25–2.5 +12.5=+35.0*
DA	–25	2	(–)1250	50	–25–2.5=(–27.5)
		Σ	+625	125	
Δ_1 for 1st loop $= \frac{-625}{2\times125} = -2.5$					
For loop BCDB (loop 2)					
BC	50	4	10000	200	50–12.5=37.5
CD	–25	3	(–)1875	75	–25–12.5=–37.5
DB (Common pipe)	–25	1	(–)625	25	–25–12+2.5=–35.0*
		Σ	7500	300	

$$\Delta_1 \text{ for 2nd loop } = \frac{-7500}{2\times300} = -12.5$$

★ *Note :* Common pipe BD (or) DB will receive corrections of both loops.

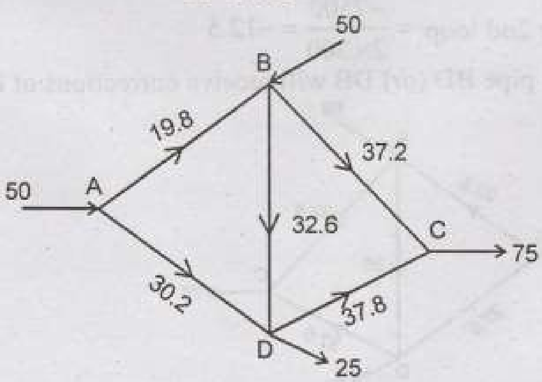


(C) Corrected flows after first correction.

Second Correction

Pipe	Assumed flow Q_a (l/s)	K(given)	$H_L=KQ_a^2$	$\left\lvert\frac{H_L}{Q_a}\right\rvert$	Corrected Q after Second correction $Q_{a2}=Q_{a1}+\Delta_2$
For loop ABDA (loop 1)					
AB	22.5	2	1012.5	45	19.8
BD (Common pipe)	35.0	1	1225.0	35	32.6*
DA	–27.5	2	–1512.5	55	–30.2
		Σ	725	135	
(For loop 1) $\Delta_2=\frac{-725}{2\times135}=(-)2.7$					
For loop BCDB (loop 2)					
BC	37.5	4	5625	150	37.2
CD	–37.5	3	–4218.75	112.5	–37.8
DB (Common pipe)	–35.0	1	–1225	35	–32.6*
		Σ	181.25	297.5	

$$\text{For loop 2} \rightarrow \Delta_2=\frac{-181.25}{2\times297.5}=-0.3$$



(D) Corrected flows after second correction

EQUIVALENT PIPE METHOD:

• In this method, a complex network of pipes is replaced by a single hydraulically equivalent pipe.

• The equivalent pipe is one which will replace a system of pipes with equal head loss for a given flow.

LEAKAGE DETECTION IN UNDERGROUND DISTRIBUTION PIPES

Leakage detection methods:

(i) By direct observation

(ii) By using sounding rods

(iii) By plotting hydraulic gradient line

(iv) By using waste detection meters.

1. By direct observations :

• Wet soft spots on unpaved ground, grasses, emergence of springs at odd places indicates leakage from underground pipes.

• Such indications will be available when pipes are laid below loamy or clayey soils.

• However, direct observation is difficult in sandy soils.

2. By using sounding rods :

• A sharp pointed metal rod is thrust into the ground along the pipe line and pulled up for inspection.

• Its moist or muddy point indicates leakage.

• The sound of escaping water can be heard by placing the ear on top of the inserted rod or by using magnifying instruments -aquaphone or sonoscope.

• The sound hearing should be done during night hours.

3. By plotting hydraulic gradient line

• The pressures at various points along a suspected pipeline are measured and the HGL is plotted.

• Any kink or change in slope of the HGL will indicate the location of leakage.

4. By using waste detection meters

• These meters measure the unusually high flows passing through the water mains during periods of low consumption (during night or early morning)

• The unusual flow indicates leakage.

• This test is conducted during night hours.

Method: The suspected locality is isolated.

• The supplies to all other areas are closed down except the suspected area.

• The meter is fitted at the head of main supply pipe and flow is recorded.

DISTRIBUTION SYSTEMS & THEIR MAINTENANCE

Introduction

Even if the water source for your small water system is of pristine quality, if the distribution system is not maintained or is in a state of disrepair, the quality of water may deteriorate before it reaches the customer.

The focus on this section is on the safe delivery of water. We will discuss the following:

Delivery of water

• Some common issues and hazards that must be avoided

• Sampling and monitoring

• Operations and maintenance

• Easements

• Leak detection and water loss

• Water metering

• The importance of a cross connection control program

PUMPING STATION

Introduction

Pumping stations are either as in-line for lifting the sewage from a deeper sewer to a shallow sewer or for pumping to the STP or the out fall. They are required where low lying development areas cannot be drained by gravity to existing sewerage infrastructure, and/or where development areas are too far away from available sewerage infrastructure to be linked by gravity. The O&M of pumping systems presented here applies to all such types of pumping stations.

Types and Structure of Pumping Stations

The type of pumping stations can be (a) Horizontal pumps in dry pit, (b) Vertical pumps in dry pit, (c) Vertical pumps in suction well and (d) Submersible pumps in suction sump. All these types include a sewage-receiving sump, which is called suction sump or wet well. These types of pump arrangements are shown in Figure 3.29.

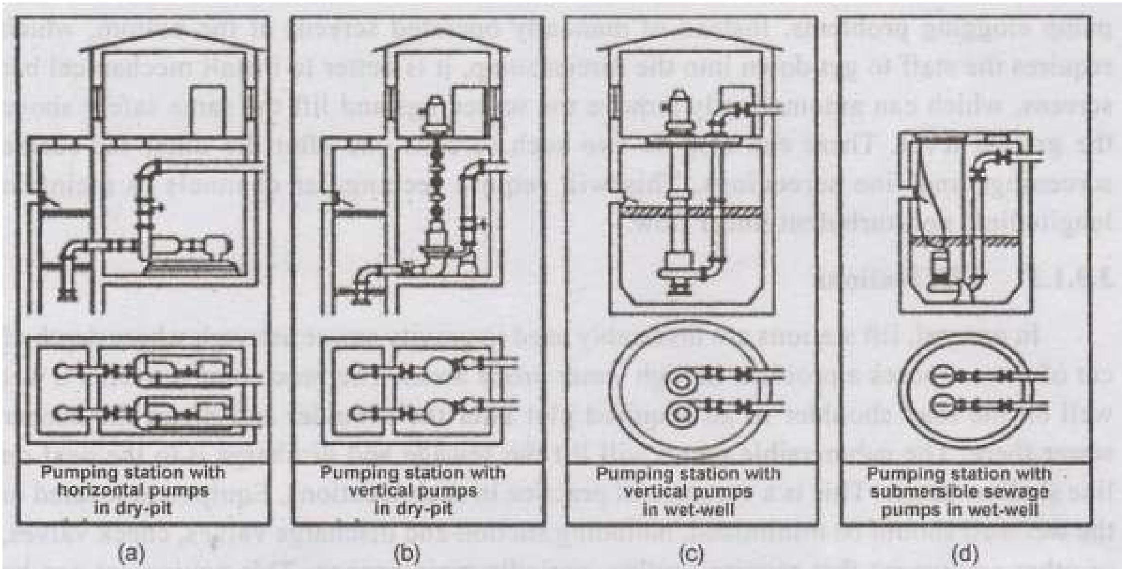


Fig.3.29 Typical drywell and wet well installations

HOUSE SERVICE CONNECTION

A typical water connection, connecting the service pipe and municipal water main is shown in figure.

The water connection consists of:

(a) Ferrule - It is a right angle sleeve made of brass or gun metal and is joined to a hole drilled in the water main and is screwed down with a plug. Its size varies between 10 to 50 mm dia.

(b) Goose neck - A small size curve pipe made of flexible material usually lead, about 75cm length forming a flexible connection between the water main and the service pipe.

(c) Service pipe - Galvanised iron pipe < 50mm dia laid underground in a trench. The service pipe is connected to the municipal main through the goose neck and ferrule.

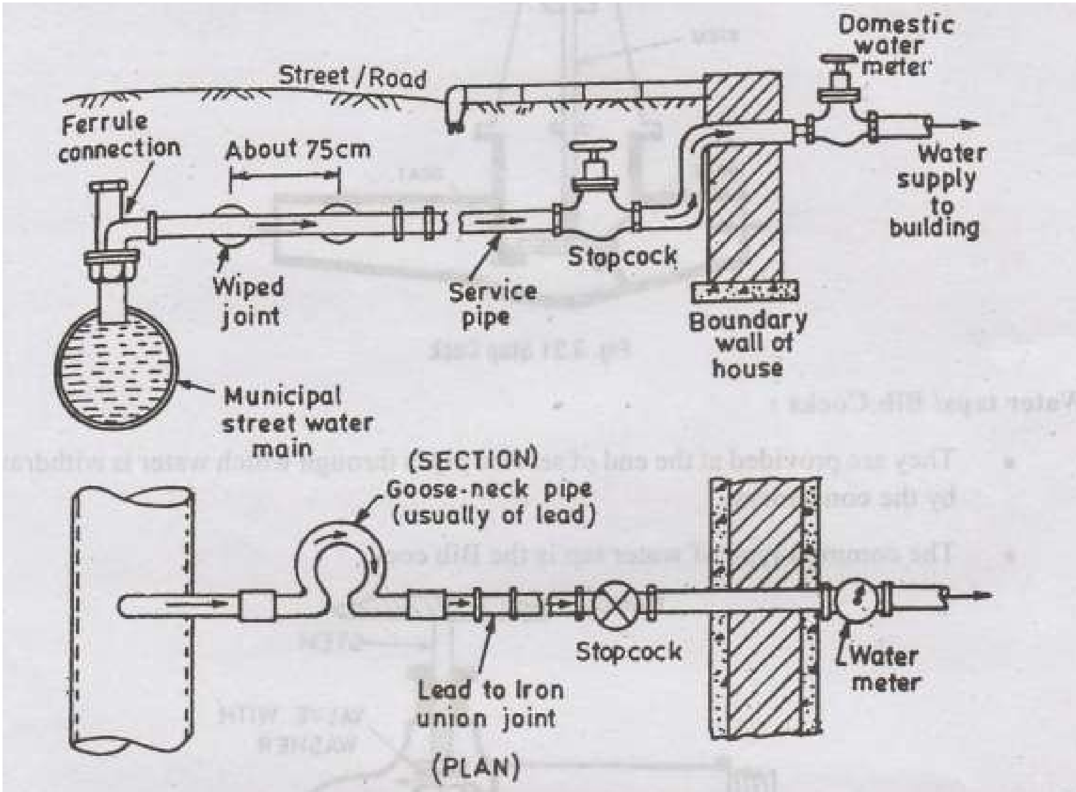


Fig. 3.30 The Water Connection

(d) Stop cock - Provided before the water meter in the house. It is housed in a masonry chamber with removable cover and fixed in the street close to the boundary wall.

(e) Water meter - Measures/ records the quantity of water consumed in the house. It is connected to service pipes by union joint. It is fixed inside iron box fitted Jooqe in cavity made in boundary wall of house and covered with movable iron cover.

Pipe fittings :

Fittings are used in making service connections.

- Bends
- Elbows
- Plugs
- Crosses
- Unions
- Flanges
- Tees
- Caps
- Nipples etc.

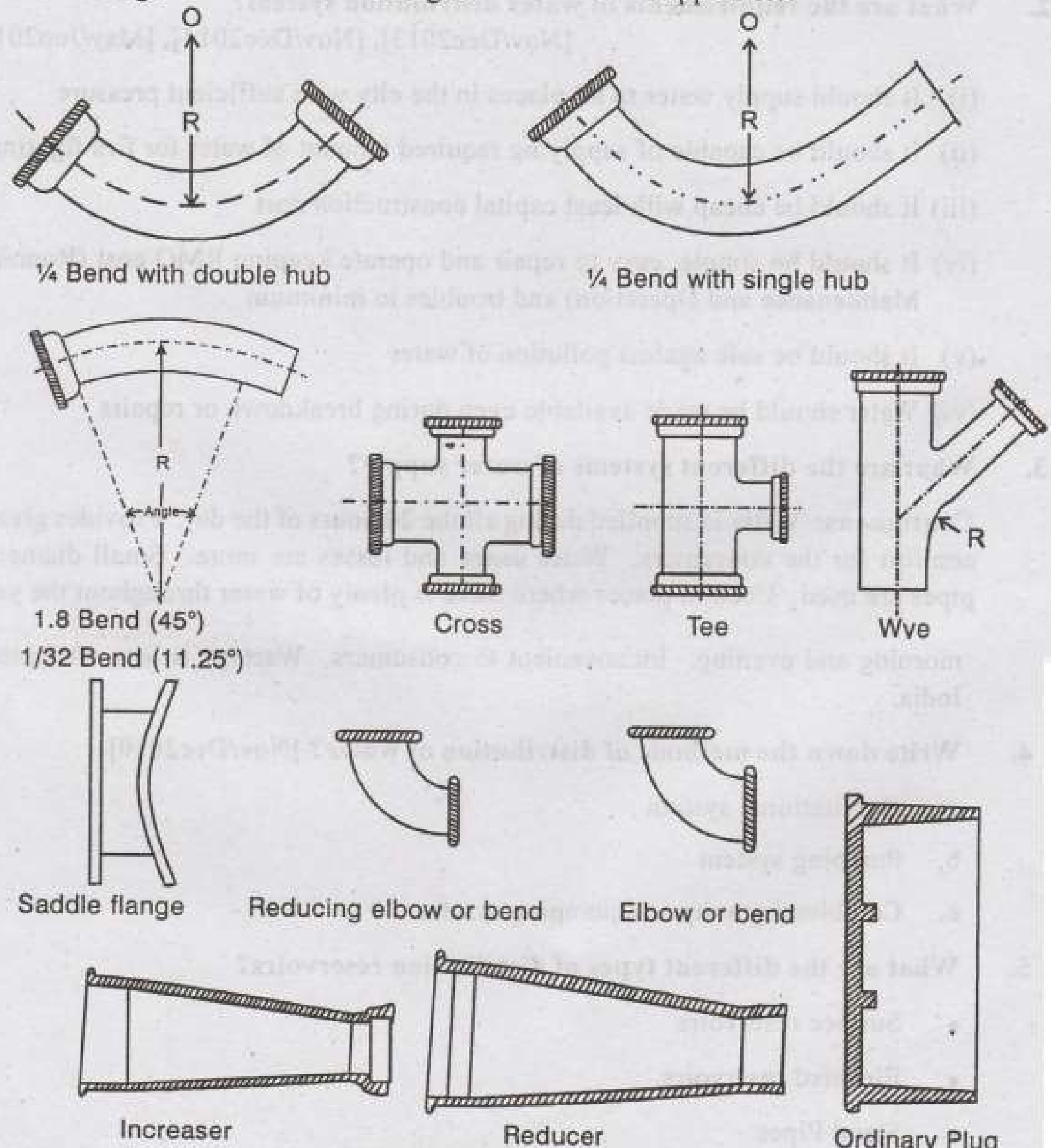


Fig. 3.33 Varou pipe fittings

Water Supply And Wastewater Engineering: Unit III: Water Storage And Distribution: Two Marks Questions And Answers

TWO MARK QUESTION AND ANSWERS

1. What do you mean by water distribution?

After treatment, water is to be stored temporarily and supplied to the consumers through the network of pipelines called distribution system. The distribution system also includes pumps, reservoirs, pipe fittings, instruments for measurement of pressure, flow, leak detectors etc.

2. What are the requirements of water distribution system?

(i) It should supply water to all places in the city with sufficient pressure

(ii) It should be capable of supplying required amount of water for fire fighting

(iii) It should be cheap with least capital construction cost

(iv) It should be simple, easy to repair and operate keeping RMO cost (Running, Maintenance and Operation) and troubles to minimum

(v) It should be safe against pollution of water

(vi) Water should be made available even during breakdown or repairs

3.What are the different systems of water supply?

Continuous: Water is supplied during all the 24 hours of the day. Provides greater comfort for the consumers. Water usage and losses are more. Small diameters pipes are used. Used in places where there is plenty of water throughout the year.

Intermittent: Water is supplied only during specific periods ie., peak hours in the morning and evening. Inconvenient to consumers. Wastage is less. Adopted in India.

4. Write down the methods of distribution of water?

a. Gravitational system

b. Pumping system

c. Combined gravity and pumping system die

5. What are the different types of distribution reservoirs?

- Surface reservoirs
- Elevated reservoirs

• Stand Pipes

6. How will you determine the capacity of storage reservoirs?

Storage reservoir capacity is equal to the sum of balancing or equalizing reserve, breakdown reserve and fire reserve. The balancing reserve is found using hydrographs and mass curve methods

7. What are prime functions of service reservoirs?

(i) They absorb hourly variations in demand by allowing the pumps to operate at constant rate to reduce RMO cost

(ii) They help in maintaining constant pressure in the distribution mains

(iii) Pumping of water in shifts can be made with service reservoirs gool bezolovne

(iv) Stored water can be used for emergencies like breakdowns and fire outbreaks

(v) Leads to overall economy by reducing sizes of pumps, pipes and treatment dily units

8. What are the layouts or networks of water distribution system?

(i) Dead end system

(ii) Grid iron system

(iii) Ring system

(iv) Radial system

9. Give the advantages and disadvantages of dead end system?

Advantages:

• Calculation of discharge and pressure is easy for the distribution network

• Number of Valves required is less

• Smaller diameter pipes can be used

• Cheap and economical

• Laying of pipes is simple

Disadvantages:

• Stagnant water at dead ends causes water contamination

• During repairs, there will be no supply in some areas obi noyob woll

• The water available for fire-fighting will be limited in quantity

10. What is Grid iron system?

Layout of the distribution system by a network of inter-connected pipes with water flowing in any direction with least resistance to flow is known as grid iron system.

11. What are the methods used for the analysis of distribution networks?

a. Hardy cross Method

b. Equivalent Pipe Method

12. What are the assumptions in Hardy Cross method?

At each junction, inflow-outflow. The algebraic sum of water entering and leaving any junction is zero.

In any closed loop, algebraic sum of head loss is zero

13. What is an equivalent pipe?

The equivalent pipe is one which will replace a given system of pipes with equal head loss for a given flow.

Principles of equivalent pipes are

(i) head loss through pipes in series are additive

(ii) head loss through pipes in parallel are same

14. What is the role of computer application in water supply system?

EPANET, BRANCH and LOOP as well as commercial softwares like Aquis, H20 map, KYPipe, WaterCAD, WaterGEMS, AUTOCAD, GIS etc. are used for the analysis of water distribution networks. They are used to determine the pipe diameter, head loss and pressure etc. These are used for hydraulic and water quality modeling, model building supported with geospatial tools.

Computer applications allows

• Allow extended period hydraulic simulations

• Possess integrated module for water quality simulations

• Handle virtually unlimited size of the network in any configuration

• Have excellent graphical interface for presentation of results

15. How do you identify leakage in pipe lines?

Leakages in pipe line can be identified by the following methods.

1) By direct observations:

Practically observing a wet soft spot on the unpaved ground or in lawn or emergence of spring in odd place

(ii) By using sounding rods

(iii) By plotting the hydraulic gradient line

(iv) By using waste detection meters

16. Name any two appurtenances used in water distribution system?

(i) Fire hydrants

(ii) Water meters

(iii) Water taps

(iv) Stop cocks

(v) Pipe bends

16. What factor control water supply to buildings?

a. Source of water supply like city mains or ground water

b. Type of water supply like continuous and intermittent

c. Pressure in water supply main

d. Head loss in pipes and fittings

e. Loss of head in top floors during peak hours in high rise buildings

f. Excess pressure in ground floor pipes

g. Location of over head tank

17. What is hydro-pneumatic system?

System of pumping water by compressed air to fixtures in a building is known as hydro pneumatic system.

18. List out the components of a service connection pipe?

a. Ferrule

b. Goose neck

c. Service pipe

d. Stop cock

e. Water meter

19. What is ferrule in water service connection?

Ferrule is a right angled sleeve made of gun metal or brass, joined to a hole drilled in the water main, to which it is screwed down with a plug. Diameter is 10-50 mm

20. What is a goose neck?

It is a 50 cm long curved piece of flexible pipe made of brass which prevents the breaking of main pipe due to the movement between water main and service pipe and provides greater flexibility at the junctions.

21. What do you mean by sanitary fitting?

Sanitary fittings are made of porcelain, stainless steel, brass and plastics which receive and transfer foul liquids and water containing solids which are produced by human activities in buildings. Sanitary fittings are sinks, wash-tubs, baths, lavatories, water-closets, sinks and urinals.

22. What are the advantages of laying pipes in parallel?

To facilitate repair works

To increase the supply to any area if required

To use smaller diameter pipes.

23. What is a distribution pipe?

Supply pipe in building from which connections to fixtures take off is called as distribution pipe.

24. What is a service pipe?

Part of house connection from the street main that is under the control of the owner of the premises.

25. What are the requirements of plumbing or piping system in buildings?

• It should not permit backflow of water

• All joints should be water tight and no leakage or spill at taps or cocks should be allowed

• Pipelines should not be carried under walls or foundations

• It should not be close to sewers or waste water drains. There should not be any • possibility for cross connections

• If pipelines are close to electric cables, proper insulation should be observed

• It should afford easy inspection and repair of fixtures and joints

• Number of joints, bends and tees should be less

• It should supply adequate discharge at fixtures

• Economical in terms of materials

• Protected against corrosion, air lock, negative pressure and noise due to flow in pipes.

26. What is meant by pipe appurtenances and mention their role?

Pipe appurtenances are components attached in pipe line which aid in the proper functioning of pipe network. Role of appurtenances are ceasing, controlling, diversion and regulating flows through the pipe network. Appurtenances are valves, tees, bends, crosses etc.

27. List out any two appurtenances in water conveyance system?

• Sluice valves or gate valves,

• Air valves,

• Reflux valves,

• Relief valves,

• Altitude valves,

• Scour valves

UNIT - IV

PLANNING AND DESIGN OF SEWERAGE SYSTEM

TERMS AND DEFINITIONS

1. Sanitary Sewage Waste Water generated from a community (residential, commercial buildings and industries) - Domestic Sewage + Industrial Sewage.

2. Domestic Sewage = Waste Water discharged from lavatory, urinals, water closets from residential and office buildings.

3. Industrial Sewage = Waste Water discharged from industrial and commercial establishment.

4. Night Soil = Human and Animal excreta.

5. Refuse sullage, Soild. Liquid and Semi-Solid waste thar includes garnages, rubbish sullage, sewage, subsoil water and storm water.

6. Garbage = Dry refuse-paper, decayed vegetables, street sweepings, organic and untreated putrifying organic matter etc.

7. Rubbish = Solid Waste like building material, furniture rags, papers, etc.

8. Sullage Waste Water from Bathroom and Kitchen.

9. Storm Water = The rain water of a locality.

10. Sewage = Liquid Waste from a community that includes sullage, discharge from urinals, latrines, industrial waste, ground and storm waters.

11. Sewerage = Structures, Devices, Equipments, Appurtenances intended for collection, transportation, pumping of sewage and liquid waste but excluding treatment of sewage.

12. Sewer It is an under-ground conduit or drain through which sewage is carried to a point of discharge or disposal.

13. Waste Water = This term is used in place of sewage. It includes both organic and mineral matter carried through liquid media.

SOURCES OF WASTEWATER GENERATION

Domestic Sources

❖ Human waste from lavatories (feces, urine, flush water); known as black water

❖ Washing water (personal, clothes, floors, dishes, etc.), known as greywater or sullage

❖ Discharge from Septic tank

❖ Cooking oil, Pesticides, Lubricating oil, Paint, Cleaning liquids, etc.

Industrial Sources

❖ Industrial process waters (Dyeing industries, Tanneries etc)

❖ Industrial cooling waters (heat)

❖ Organic or biodegradable waste

❖ Organic or non bio-degradable/difficult-to-treat waste (pharmaceutical or pesticide manufacturing)

❖ Extreme pH waste (from acid/alkali manufacturing, metal plating)

❖ Toxic waste (metal plating, cyanide production, pesticide manufacturing, etc.)

❖ Solids and emulsions (paper manufacturing, foodstuffs, lubricating and hydraulic oil manufacturing, etc.)

❖ Waste water from oil & natural gas production

Rainfall collected on roofs, yards, roads, carparks, pavements etc; known as storm runoff

Workshops and garages (gasoline/petrol/diesel or rubber residues, soap scum, metals from vehicle exhausts, etc.)

Discharge from Sewage Treatment Plant (STP)

Groundwater infiltration into sewers

❖ Seawater ingress (salt and microbes)

❖ Agricultural drainage

EFFECTS OF WASTE WATER

In developing countries, waste water is directly disposed into water bodies or on land with or without proper treatment, which leads to the following issues:

1. Unsightly appearance

2. Odour nuisance - Gases released from sewage cause foul smell.

3. Nuisance of mosquito breeding, flies, rodents, insects etc

4. Outbreak of Diseases/Epidemics: Waste water contains numerous pathogens (disease causing microorganisms) and improper disposal may cause serious diseases and illness to urban and rural population.

5. Water Pollution: When waste water is discharged into fresh water bodies (rivers, lakes etc), numerous pollutants are released into it and the oxygen level of water depletes. The water becomes unfit for human use. This water may even become fatal if given to infants (Blue Baby Syndrome).

6. Land Pollution: Caused due to the harmful and toxic chemicals in waste water.

7. Ground Water Contamination : Waste water discharged on land, percolates through the soil and pollutes underground water sources and renders it unsuitable for use.

8. Contamination of drinking water supplies

9. Ecological imbalance: When waste water is discharged into water bodies, the aquatic plants and animals are affected which may alter the ecosystem.

Eg: When waste water is discharged into lakes, due to the high concentration of dgir dw Nutrients in it, algae grows in excess and covers the lake surface, which prevents

sunlight penetration into water and thereby depletes the oxygen level of water. This condition is called Eutrophication. The water in the lake becomes septic and unfit for human use. The aquatic life (fishes, insects, worms etc) cannot survive without oxygen and in and this leads to imbalance in the lake ecosystem.

CHARACTERISTICS AND COMPOSITION OF SEWAGE AND THEIR SIGNIFICANCE

The quality of sewage can be checked and analysed by studying and testing its physical, chemical and bacteriological characteristics.

Physical Characteristics of Sewage

(i) Physical characteristics include:

(i) Colour

(ii) Odour

(iii) Temperature and

(iv) Turbidity,

(i) Colour:

❖ The colour of sewage can normally be detected by the naked eye, and it indicates the freshness of sewage.

❖ If the colour is yellowish, grey, (or) light brown, it indicates fresh sewage.

❖ If the colour is black (or) dark brown, it indicates stale and septic sewage.

❖ Industrial waste water imparts colour to sewage and the color depends on the chemical process in industries.

(ii) Odour:

❖ Fresh sewage is practically odourless.

❖ After 3 to 4 hours, it becomes stale when all the oxygen present in sewage gets exhausted.

❖ After few hours, it starts omitting offensive odours, especially (H,S) hydrogen zsulphide gas, due to decomposition of sewage.

(iii) Temperature:

❖ Affects the biological activity of bacteria present in sewage. When temperature is high, the bacteria will be more active in decomposition of waste in sewage.

❖ When temperature is high, the solubility of gases in sewage reduces.

(iv) Turbidity:

❖ Solids in suspension cause turbidity.

❖ Sewage is normally turbid, having floating matter like pieces of paper, match sticks, greases, vegetable dehris, fruit skins, soaps, etc.

❖ The turbidity increases as sewage becomes stronger.

Chemical Characteristics of Sewage

(i) Total Solids

❖ Sewage normally contains very small amount of solids (0.05 to 0.1%) in relation tabiat to the huge quantity of water (99.9%). borgiow It only contains about 0.05 to 0.1 percent (i.e., 500 to 1000 mg/L) of total solids.

Classification

(i) Suspended solids are solids which remains floating in sewage.

(ii) Dissolved solids remain dissolved in sewage.

(iii) Colloidal solids are finely divided solids remaining either in solution (or) in suspension.

(iv) Settleable solids are solids which settle out, if sewage is allowed to remain undisturbed for a period of 2 hours.

❖ The solids can also be categorised as:

(a) Organic Solids,

(b) Inorganic Solids.

❖ The organic matter is about 45% of total solids and remaining 55% is inorganic matter.

❖ Inorganic matter consists of minerals, salts, sand, gravel, debris, chlorides, sulphates, etc. The presence of inorganic solids in sewage is not harmful and requires simple treatment.

❖ Organic matter consists of carbohydrate (cellulose, cotton, fibre, starch, sugar, etc.), Fats and oils received from kitchens and Nitrogeneous compounds like protein. Organic matter in sewage requires proper treatment before disposal in water bodies.

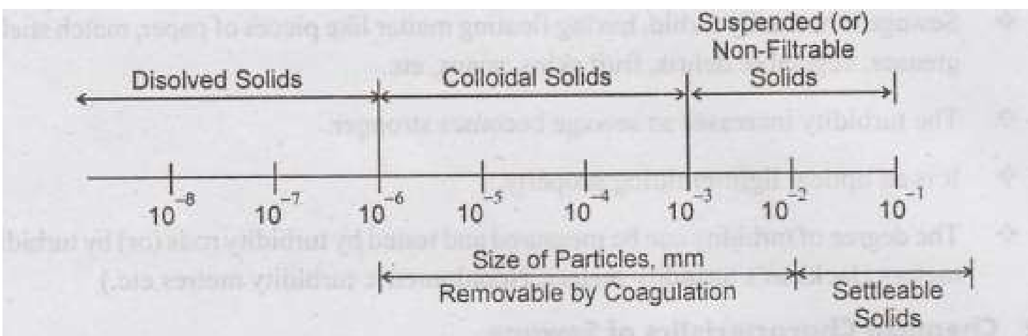


Fig. 4.1 : Classification of Solids

(ii) pH Value:

❖ pH value indicates negative log of hydrogen ion concentration

pH = -log H+ (or) H+ = (10)-pH

pH <7-acidic range

pH > 7 - alkaline range.

❖ The fresh sewage is generally alkaline in nature (pH more than

❖ But as time passes, sewage turns acidic and its pH tends to fall due to production of acids by bacterial action.

❖ The pH value can be measured quickly and automatically with the help of potentiometer, which measures the electrical potential exerted by the hydrogen $2015 ions.

❖ The efficiency of sewage treatment depends on pH.

❖ If pH of sewage is low, lime is added to create alkaline condition.

(iii) Chloride Contents:

❖ Chlorides are generally found in domestic sewage, and are derived from the kitchen wastes, urinary discharges, feces etc.

❖ Large amount of chlorides may enter from industries like ice cream plants, meat salting industries.

❖ Chloride in sewage may also be due to infiltration of sea water ($NaCl$).

❖ The normal chloride content of domestic sewage is 120 mg/l.

❖ The chloride content can be measured by titrating the waste water with standard silver nitrate AgNO, solution using potassium chromate as indicator.

(iv) Nitrogen Contents:

❖ The presence of nitrogen in sewage indicates the presence of organic matter, and it may occur in any of the following forms.

a) Free ammonia called ammonia nitrogen.

b) Albuminoid nitrogen, called organic nitrogen.

c) Nitrites and

d) Nitrates.

NH3 ↑ +H20 NH4++OH-

If further oxidation occurs as

NH4++ 202 → NO3-+2H++H20

❖ The sewage treatment is done using microorganisms which decompose the organic waste into stable compounds.

❖ The presence of nitrogen in various forms is indicative of the stages of decomposition and level of treatment.

❖ The free ammonia indicates the age of waste water and the very first stage of nogobert decomposition of organic matter.

❖ Albuminoid nitrogen indicates quantity of nitrogen in sewage before the decomposition of organic matter is started.

❖ The nitrites indicate the presence of partly decomposed (not fully oxidised) organic matter viz., treatment is in progress.

❖ The nitrates indicate the presence of fully oxidised organic matter viz., treatment is complete.

(v) Presence of Fats, Oils and Greases:

❖ Greases, fats and oils are derived in sewage from the dischages of animals, vegetable matter from garages, hotels, restaurants and industries etc.

❖ They interfere with sewage treatment and they form scum on the top of sedimentation tanks and clog the voids of the filtering media.

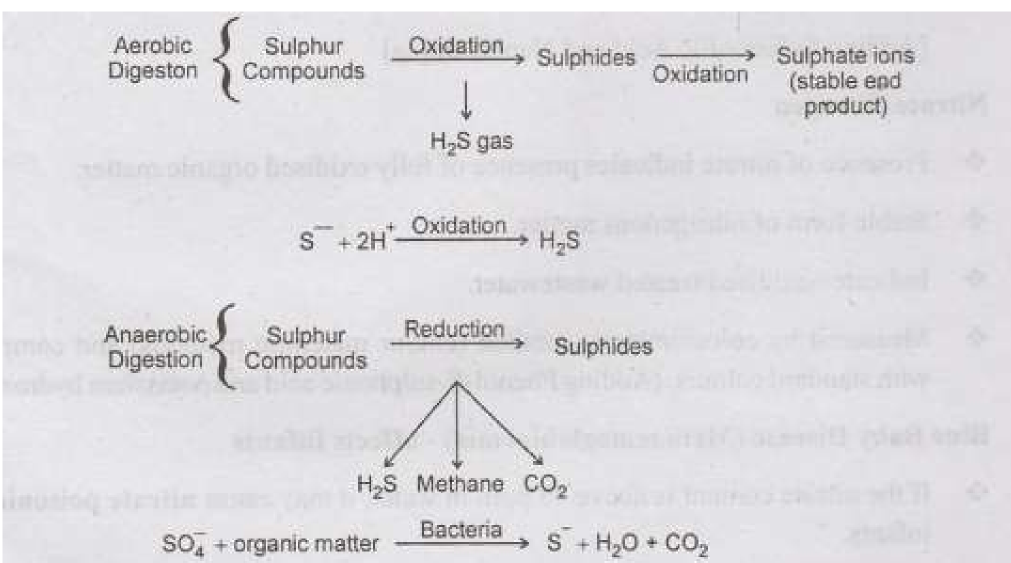
❖ They are not decomposible by bacterial action and therefore should be removed from sewage.

❖ Measured by evaporating sewage sample, residual solids left after evaporation are mixed with ether (hexane) and again evaporated, leaving behind the fats and greases as a residue, which can be weighed.

(vi) Sulphides, Sulphates and Hydrogen Sulphide Gas:

❖ Formed due to the decomposition of various sulphur containing substances in sewage.

❖ This decomposition also leads to evolution of hydrogen sulphide (H,S) gas, causing bad smells odours and corrodes the sewer pipes.



❖ Formation of sulphides hinders the process of sludge digestion.

(vii) Dissolved Oxygen (D.O):

❖ D.O. is the oxygen present in dissolved state in waste water, which prevents noxious odours.

❖ D.O test performed on sewage before treatment helps in indicating the condition of sewage and decides selection of treatment methods.

❖ Fresh sewage contains some dissolved oxygen, which is soon depeleted by aerobic decomposition.

❖ Presence of D.O. in treated sewage indicates oxidation during treatment stages.

❖ Treated sewage effluent should have atleast 4 ppm D.O. in it, otherwise it will affect the aquatic life when sewage is discharged into water bodies.

❖ The dissolved oxygen in fresh sewage depend upon temperature.

❖ If the temperature of the sewage is more, the D.O content will be less.

❖ The D.O content of sewage is determined by Winkler's method which is an oxidation-reduction process, wherein iodine liberated is equivalent to the D.O.

(viii) Oxygen Demand:

❖ Oxygen required for oxidation of both inorganic as well as organic matter.

BOD - Biochemical Oxygen Demand.

COD - Chemical Oxygen Demand.

TOD - Total Oxygen Demand.

ThOC - Theoretical Oxygen Demand.

TOC - Total Organic Carbon.

(ix) Chemical Oxygen Demand (COD):

❖ Measure of Oxygen (O_2) required to oxidise organic matter in sewage into CO_2, H_2O and oxidised species.

❖ Chemicals are used to oxidise both biologically active and inactive organic matter in sewage.

❖ COD test - Oxidation using potassium dichromate.

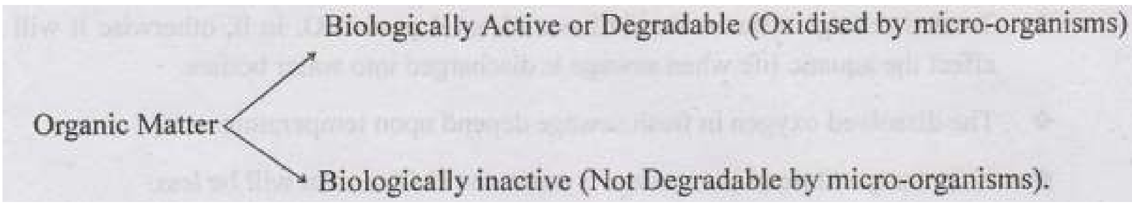
❖ A known quantity of waste water is mixed with known quantity of potassium dichromate and the mixture is heated. The organic matter is oxidised by $K_2Cr_2O_7$ (in the presence of H_2SO_4). The resulting solution of $K_2Cr_2O_7$ is titrated with Ferrous Ammonium Sulphate

(FAS) and the oxygen used in oxidising the waste water is determined. This is called Chemical Oxygen Demand (COD).

$$\underset{\text{Organic Matter}}{C_a H_b O_c} + Cr_2 O_7^{--} + H^+ \xrightarrow{\text{Catalyst Heat}} Cr^{3+} + CO_2 + H_2O$$

(x) Biological Oxygen Demand (BOD):

❖ Measure of oxygen required to oxidise biologically active organic matter in sewage by microorganisms.



* Biologically Active → The organic matter which can be oxidised by microorganisms is called biologically active (under aerobic conditions at standard temperature).

* Significance of BOD:

BOD of waste water decides the following: noir

(1) Quantity of O2 required for biological stabilization of organic matter in sewage.

(2) Size of treatment facilities.

(3) Measure of efficiency of treatment.

(4) Dilution required for disposal of waste water.

Aerobic bacteria utilises the organic matter and oxygen in sewage and starts multiplying, the bacterial count increases which causes faster decomposition of organic matter in sewage. The oxygen consumed by the bacteria for decomposition of organic matter in sewage is BOD.

Practically it is not feasible to determine the ultimate BOD.

Hence BOD at 20°C during 5 days is taken which is 68% of the total BOD.

BOD5d =0.68 BOD

BOD5 = 5 day BOD

BOD u = Ultimate BOD.

* BOD5/BOD Test: (Dilution Method)

❖ Known volume of sewage sample is diluted with known volume of aerated pure water.

❖ Diluted sample is incubated for 5 days at 20°C.

❖ The D.O of the diluted sample before and after incubation period is measured.

❖ The difference between the initial D.O value and final D.O value indicates the oxygen consumed by microorganisms in 5 days (causing aerobic decomposition).

BOD/BOD, = D.O consumed by diluted sample x

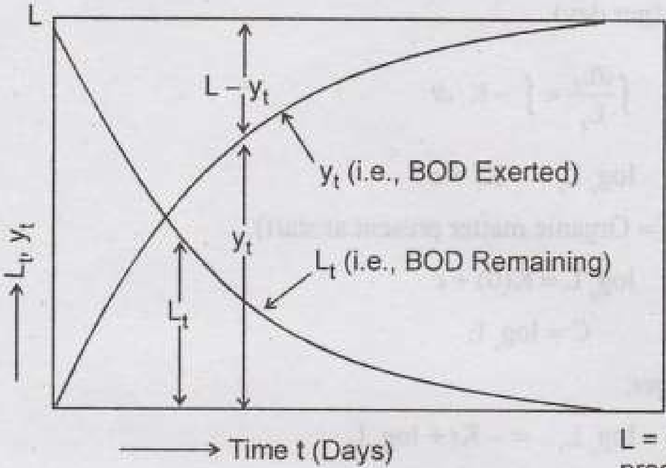
[Volume of diluted sample /Volume of undiluted sample]

[DF = 1% = 1 ml. of sewage diluted to make 100 ml, hence multiplied by 100]. Normally, 300 ml BOD test bottles are used

If 4 ml of sewage sample is taken - Incubation at 20°C-5 days.

$$\text{Dilution Factor} = \frac{300}{4}$$

$$BOD_5 = \text{D.O consumed} \times \left(\frac{300}{4}\right)$$



L = Organic matter present at start (t = 0)

Fig. 4.3 : First Stage BOD Curve

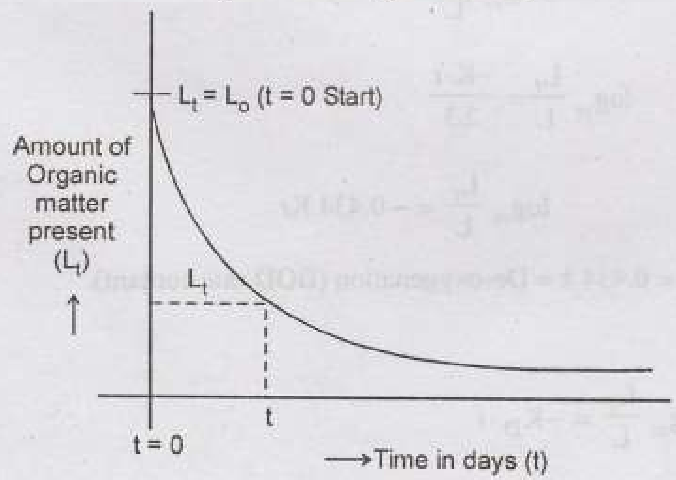


Fig. 4.4 : BOD Curve

$$\frac{dL_t}{dt} = -KL_t \quad \text{... (1)}$$

t = time in days

k = BOD rate constant (per day).

Integrating, $$\int \frac{dL_t}{L_t} = \int -K \cdot dt$$

$$\log_e L_t = -Kt + c \quad \text{... (2)}$$

When $t = 0$, $L_t = L$ (L = Organic matter present at start).

$$\log_e L = K(0) + c$$

$$C = \log_e L$$

Substituting in (2) we get,

$$\log_e L_t = -Kt + \log_e L$$

$$\log_e \frac{L_t}{L} = -Kt$$

$$2.3 \log_{10} \frac{L_t}{L} = -Kt$$

(or) $$\log_{10} \frac{L_t}{L} = \frac{-K \cdot t}{2.3}$$

$$\log_{10} \frac{L_t}{L} = -0.434\,Kt$$

$K_D = 0.434\,k$ = De-oxygenation (BOD rate contant).

We have,

$$\log_{10} \frac{L_t}{L} = -K_D \cdot t$$

$$\frac{L_t}{L} = (10)^{-K_D \cdot t} \quad \text{... (3)}$$

Now L is the organic matter present at the start of BOD reaction and L, is the organic matter left after t days, which means that during t days, the quantity of organic matter oxidised = L-Li

If Y, represent the total amount of organic matter oxidised in t days, then we have,

$$BOD_{t\ days} = Y_t = L - L_t.$$

Taking L out of bracket on R.H.S.

$$Y_t = L\left[1 - \frac{L_t}{L}\right]$$

Substituting equation (3),

$$\text{BOD of t days} = Y_t = L\left[1-(10)^{-K_D \cdot t}\right] \quad \text{... (4)}$$

Yt is the oxygen absorbed in t days.

Ultimate BOD (Yu)i.e., When t= ∞ days.

$$Y_u = L\left(1-(10)^{-K_D \cdot \infty}\right)$$

Yu =L = Ultimate BOD = Organic matter in sewage.

The ultimate BOD (Yu) is equal to the oxygen equivalent organic matter present in sewage (L).

BOD rate constant (KD)

The value of KD determines the speed of the BOD reaction.

❖BOD rate constant is temperature dependent.

❖ KD is higher at higher temperature and rate of oxidation will be faster.

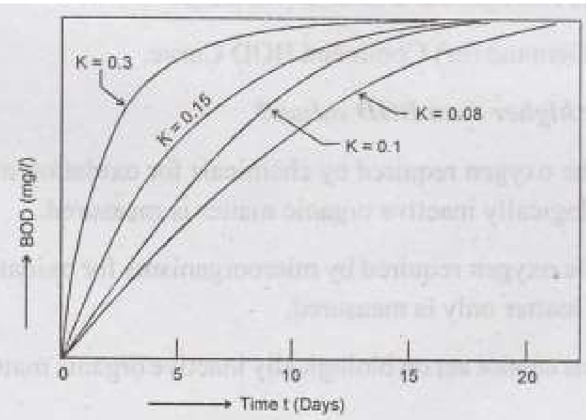


Fig. 4.5 : Effect of K on BOD

$$k_D\,(T^o) = k_D\,(20^o)\,\theta^{T-20^o}$$

$$k_D\,(T^o) = k_D\,(20^o)\,[1.047]^{T-20}.$$

$k_D\,(20^o)$ = De-oxygenation constant at 20°C (0.05 – 0.2/day)

$k_D\,(T^o)$ = De-oxygenation constant at temperature T°C.

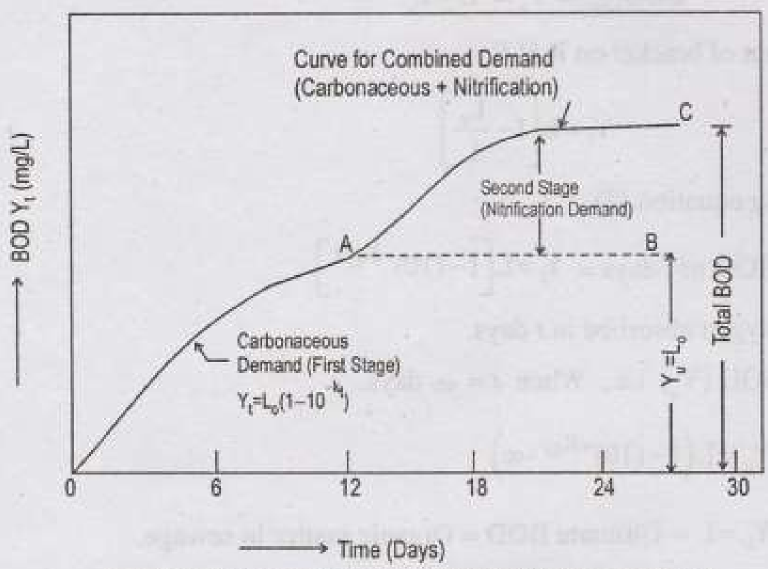


Fig. 4.6 : Combined Carbonaceous and Nitrification Demand

The oxygen demand during the first 20 days is due to oxidation of organic matter in sewage and is called Carbonaceous BOD or first stage demand (CBOD). The latter oxygen demand occurs due to biological oxidation of ammonia and is called as second stage BOD or nitrogenous BOD (NBOD).

OAB - 1st stage (or) Carbonaceous Stage (CBOD).

AC - 2nd stage (or) Nitrogenous Demand (NBOD).

OAC - Combined Demand (or) Combined BOD Curve.

* Why COD values are higher than BOD values?

❖ In COD test, the oxygen required by chemicals for oxidation of both biologically active and biologically inactive organic matter is measured.

❖ But in BOD, the oxygen required by microorganisms for oxidation of biologically active organic matter only is measured.

❖ Microorganisms cannot act on biologically inactive organic matter and hence COD > BOD.

❖ BOD to COD ratio

BODu BOD = Measure of Biodegradable organics.

COD = Measure of both Biodegradable + Non-Biodegradable organics.

Since COD > BOD => BODu/ COD ratio always < 1

If ratio = 0.92 to 1.0 = Waste water is fully biodegradable.

BOD_5 /COD = 0.63 to 0.68 →→ Indicates that Wastewater can be biologically treated → Indicates minimum quantity of non-biodegradable organic matter.

... BOD_5= 0.68 BODu

(xi) Total Organic Carbon (TOC) and Theoretical Oxygen Demand (Th.OD)

❖ Carbon is the primary constituent of organic matter. TOC therefore gives a measure of organic matter in sewage.

❖ Organic matter is expressed as carbon content.

❖ Chemical formula (Cn Hn On Nn) and concentration of compounds present in wastewater enables us to calculate theoretically the carbon content in wastewater per litre of solution.

(Cn Hn OnNn) → Carbon, Hydrogen, Oxygen, Nitrogen

For example:

$$\text{Glucose} \quad C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O$$

$$(12\times6+1\times12+16\times6) + (6\times2\times16) \qquad (6\times12+6\times2\times16)+(6\times2\times1+6\times16)$$

$$180 \qquad 192 \qquad 264 \qquad 108 \qquad \begin{bmatrix} \because C-12 \\ H-1 \\ O-16 \end{bmatrix}$$

180 mg of glucose requires 192 mg of O_2.

$$\therefore \text{ Theoretical } O_2 \text{ demand of glucose} = \frac{192}{180}\ \frac{mg}{mg}$$

$$= 1.07 \text{ mg of } O_2\text{/mg of glucose.}$$

Glucose has 6 molcules of carbon.

$$\text{Hence, carbon content of glucose} = \frac{12\times6}{180} = 0.4 \text{ mg C/mg.}$$

If 200 mg/*l* of glucose is present in waste water, then

$$\text{Th.OD} = 1.07 \text{ mg/mg} \times 200 \text{ mg}/l = 214 \text{ mg}/l.$$

$$(\text{TOC})\ C_{content} = 0.4 \text{ mg C/mg} \times 200 \text{ mg}/l = 80 \text{ mg C}/l.$$

$$\Rightarrow \frac{COD}{TOC} \text{ ratio}$$

$$C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O$$

$$\frac{COD}{TOC} = \frac{6 \text{ mol. of } O_2}{6 \text{ mol. of C}} = \frac{6\times16\times2}{6\times12} = 2.66$$

Ratio changes with biological oxidation.

POPULATION EQUIVALENT (STRENGTH OF INDUSTRIAL SEWAGE)

❖ Population equivalent is used to calculate the quantity of industrial sewage. As it is a tedious process, the industrial sewage (or) waste water is compared with the rate of generation of domestic waste water.

❖ This parameter is used to charge the industries for causing pollution (or) discharging waste water against the discharge norms and also to choose appropriate treatment methods.

Strength of Industrial Sewage (BOD5 days) = [Standard BOD5 days of domestic sewage per person per day] x [Population equivalent]

BOD5 of domestic sewage = 0.08 kg/day/person.

e.g.: If BOD5 of industrial sewage = 300 kg/day, then

Population equivalent = 300 / 0.08 = 3750.

SANITARY SEWAGE FLOW ESTIMATION

Sanitary Sewage is the spent water of a community that drains into sewers.

Sanitary Sewage = Domestic Sewage + Industrial Sewage

Theoretically speaking, the quantity of sewage (i.e., domestic sewage + industrial sewage) that is likely to enter the municipal main sewers should be equal to the quantity of water supplied to the contributing area.

i.e., Quantity of Sewage = Quantity of water supplied.

But certain additions and subtractions do take place

(i) Additions due to unaccounted private water supply. Janissonship institue vand bluorta bassidub

(ii) Addition due to ground water infiltration.

(iii) Subtractions due to water losses (leakage, seepage in ground).

(iv) Subtractions due to water lost in evaporation.

Net Quantity of sewage produced-Quantity of water supplied + (i) + (ii)–(iii)–(iv)

Net Quantity of sewage produced-Quantity of water supplied + (i) + (ii)–(iii)–(iv)

* Usually 80% of water supply may be expected to reach the sewers.

Quantity of Sewage = Per capita sewage contributed per day x Population.

Factors affecting Dry Weather Flow (DWF):

Dry Weather Flow (DWF) is the flow of sanitary sewage alone in the absence of storm

water (during dry season).

(i) Rate of water supply.

(ii) Population growth.

(iii) Type of area served (Residential/Commercial/Industrial).

(iv) Infiltration of sub soil water (leaky joint in sewers and high water table level).

SEWER MATERIALS

1. Important Factors Considered for Selecting Material

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

a. Resistance to Corrosion: Sewer carries wastewater that releases gases such as H,S. This gas in contact with moisture can be converted into sulfuric acid. The 10 nogen formation of acids can lead to the corrosion of sewer pipe. Hence, selection of jabnuong corrosion resistance material is must for long life of pipe.

b. Resistance to Abrasion: Sewage contain considerable amount of suspended solids, part of which are inorganic solids such as sand or grit. These particles moving at high velocity can cause wear and tear of sewer pipe internally. This abrasion can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough.

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

d. Weight of the Material: The material selected for sewer should have less specific weight, which will make pipe light in weight. The lightweight pipes are easy for handling and transport.

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

f. Economy and Cost: Sewer should be less costly to make the sewerage scheme economical.

g. Hydraulically efficient: The sewer shall have smooth interior surface to have less frictional coefficient.

Materials for Sewers

Asbestos Cement Sewers

• These are manufactured from a mixture of asbestos fibers, silica and cement. Asbestos fibers are thoroughly mixed with cement to act as reinforcement.

• These pipes are available in size 10 to 100 cm internal diameter and length up to 4.0 m.

• These pipes can be easily assembled without skilled labour with the help of special gnuto coupling, called 'Ring Tie Coupling' or Simplex joint.

• The pipe and joints are resistant to corrosion and the joints are flexible to permit 12° deflection for curved laying.

• These pipes are used for vertical transport of water. For example, transport of rainwater from roofs in multistoried buildings, for transport of sewage to grounds, and for transport of less foul sullage i.e., wastewater from kitchen and bathroom.

Advantages

• These pipes are light in weight and hence, easy to carry and transport.

• Easy to cut and assemble without skilled labour.

• Interior is smooth (Manning’s n = 0.011) hence, can make excellent hydraulically efficient sewer.

Disadvantages

• These pipes are structurally not very strong.

• These are susceptible to corrosion by sulphuric acid. When bacteria produce H2S, in presence of water, H2,SO4 can be formed leading to corrosion of pipe material.

Plain Cement Concrete or Reinforced Cement Concrete

Plain Cement Concrete (1: 1.5: 3) pipes are available up to 0.45 m diameter and reinforcement cement pipes are available up to 1.8 m diameter. These pipes can be cast in situ or precast pipes.

Precast pipes are better in quality than the cast in situ pipes. The reinforcement in these pipes can be different such as single cage reinforced pipes, used for internal pressure less than 0.8 m; double cage reinforced pipes used for both internal and external pressure greater than 0.8 m; elliptical cage reinforced pipes used for larger diameter sewers subjected to external pressure; and Hume pipes with steel shells coated with concrete from inside and outside. Nominal

longitudinal reinforcement of 0.25% is provided in these pipes.

Advantages of Concrete Pipes

• Strong in tension as well as compression.

• Resistant to erosion and abrasion.

• They can be made of any desired strength.

• Easily molded, and can be in situ or precast pipes.

• Economical for medium and large sizes.

• These pipes are available in wide range of size and the trench can be opened and backfilled rapidly during maintenance of sewers.

Disadvantages

• These pipes can get corroded and pitted by the action of H2SO4.

• The carrying capacity of the pipe reduces with time because of corrosion.

• The pipes are susceptible to erosion by sewage containing silt and grit.

The concrete sewers can be protected internally by vitrified clay linings. With protection lining they are used for almost all the branch and main sewers. Only high alumina cement concrete should be used when pipes are exposed to corrosive liquid like sewage

Vitrified Clay or Stoneware Sewers

These pipes are used for house connections as well as lateral sewers. The size of the pipe available is 5 cm to 30 cm internal diameter with length 0.9 to 1.2 m. These pipes are rarely manufactured for diameter greater than 90 cm. These are joined by bell and spigot flexible compression joints.

Advantages

- Resistant to corrosion, hence fit for carrying polluted water such as sewage.
- Interior surface is smooth and is hydraulically efficient.
- The pipes are highly impervious.
- These pipes are durable and economical for small diameters.
- The pipe material does not absorb water more than 5% of their own weight, when immersed in water for 24 h.

Disadvantages

- Heavy, bulky and brittle and hence, difficult to transport.
- These pipes cannot be used as pressure pipes, because they are weak in tension.

Brick Sewers

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

Cast Iron Sewers

These pipes are stronger and capable to withstand greater tensile, compressive, as well as bending stresses. However, these are costly. Cast iron pipes are used for outfall sewers, rising mains of pumping stations, and inverted siphons, where pipes are running under pressure. These are also suitable for sewers under heavy traffic load, such as sewers below railways and highways. They are used for carried over piers in case of low lying areas. They form 100% leak proof sewer line to avoid groundwater contamination. They are less resistant to corrosion; hence, generally lined from inside with cement concrete, coal tar paint, epoxy, etc. These are joined together by bell and spigot joint. IS:1536-1989 and IS:1537-1976 provides the specifications for spun and vertically cast pipes, respectively.

Steel Pipes

These are used under the situations such as pressure main sewers, under water crossing, bridge crossing, necessary connections for pumping stations, laying pipes over self supporting spans, railway crossings, etc. They can withstand internal pressure, impact load and vibrations much better than CI pipes. They are more ductile and can withstand water hammer pressure better. These pipes cannot withstand high external load and these pipes may collapse when negative pressure is developed in pipes. They are susceptible to corrosion and are not generally used for partially flowing sewers. They are protected internally and externally against the action of corrosion.

Ductile Iron Pipes

Ductile iron pipes can also be used for conveying the sewers. They demonstrate higher capacity to withstand water hammer. The specifications for DI pipes is provided in IS:12288-1987. The predominant wall material is ductile iron, a spheroidized graphite cast iron. Internally these pipes are coated with cement mortar lining or any other polyethylene or poly wrap or plastic bagging/sleeve lining to inhibit corrosion from the wastewater being conveyed, and various types of external coating are used to inhibit corrosion from the environment. Ductile iron has proven to be a better pipe material than cast iron but they are costly. Ductile iron is still believed to be stronger and more fracture resistant material. However, like most ferrous materials it is susceptible to corrosion. A typical life expectancy of thicker walled pipe could be up to 75 years, however with the current thinner walled ductile pipe the life could be about 20 years in highly corrosive soils without a corrosion control program like cathodic protection.

Plastic Sewers (PVC pipes)

Plastic is recent material used for sewer pipes. These are used for internal drainage works in house. These are available in sizes 75 to 315 mm external diameter and used in drainage works.

They offer smooth internal surface. The additional advantages they offer are resistant to corrosion, light weight of pipe, economical in laying, jointing and maintenance, the pipe is tough and rigid, and ease in fabrication and transport of these pipes.

High Density Polythylene (HDPE) Pipes

Use of these pipes for sewers is recent development. They are not brittle like AC pipes and other pipes and hence hard fall during loading, unloading and handling do not cause any damage to the pipes. They can be joined by welding or can be jointed with detachable joints up to 630 mm diameter (IS:4984-1987). These are commonly used for conveyance of industrial wastewater.

They offer all the advantages offered by PVC pipes. PVC pipes offer very little flexibility and normally considered rigid; whereas, HDPE pipes are flexible hence best suited for laying in hilly and uneven terrain. Flexibility allows simple handling and installation of HDPE pipes. Because of low density, these pipes are very light in weight. Due to light in weight, they are easy for handling, this reduces transportation and installation cost. HDPE pipes are non corrosive and offer very smooth inside surface due to which pressure losses are minimal and also this material resist scale formation.

Glass Fiber Reinforced Plastic Pipes

This martial is widely used where corrosion resistant pipes are required. Glass fiber reinforced plastic (GRP) can be used as a lining material for conventional pipes to protect from internal or external corrosion. It is made from the composite matrix of glass fiber, polyester resin and fillers. These pipes have better strength, durability, high tensile strength, low density and high corrosion resistance. These are manufactured up to 2.4 m diameter and up to 18 m length (IS:12709-1989). Glass reinforced plastic pipes represent the ideal solution for transport of any kind of water, chemicals, effluent and sewage, because they combine the advantages of corrosion resistance with a mechanical strength which can be compared with the steel pipes. Typical properties that result in advantages in GRP pipes application can be summarized as follows:

- Light weight of pipes that allows for the use of light laying and transport means.

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

Lead Sewers

- They are smooth, soft and can take odd shapes.
- This pipe has an ability to resist sulphide corrosion.
- However, these pipes are very costly.
- These are used in house connection.

HYDRAULICS OF FLOW IN SEWERS

Factors that influence flow of sewage in sewers.

- Slope of sewer.
- Geometry of sewer.

• Roughness of interior surface of sewer.

• Bends, transitions, obstructions etc.

• Flow conditions.

• Characteristics of sewage.

Hydraulic Formulae:

(i) Chezy's Formula:

$V=C\sqrt{R.S}$

V = Velocity of flow (m/s)

S = Hydraulic gradient of sewer

R = Hydraulic mean radius (m) = A/P

C = Chezy's constant

A = Area of cross-section (m^2)

P = Wetted perimeter (m)

Chezy's constant C is found using Bazin's formula:

Q=AV

Q = Discharge in m^3/s.

(ii) Kutter's Formula:

$$\text{Chezy's coefficient, } C = \frac{23 + \frac{0.00155}{S} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{N}{\sqrt{R}}}$$

R = Hydraulic mean radius

S = Slope

N = Rugosity co-efficient (depends on nature of inner surface of sewer)

When N decreases, diameter increases.

Example: For Cement concrete sewer of 600 mm, N = 0.013.

(iii) Bazin's Formula:

Chezy's constant, $$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{R}}}$$

K - Bazin's constant (Depends on nature of inner surface of sewers).

(iv) Manning's Formula:

Velocity of flow,

$$V = \frac{1}{N} R^{2/3} S^{1/2},$$

where N, R, S have same meaning as given by Kutter's formula.

(v) Crimp and Burge's Formula:

V=83.5 R2/3 S1/2

(Similar to Manning's formula where 1/N =83.5 or N = 0.012).

Example: For a circular pipe,

$$R = \frac{A}{P} = \frac{\pi/4 D^2}{\pi D} = \frac{D}{4}$$

$$V = 83.5\,(D/4)^{2/3} \cdot S^{1/2}$$

$$Q = A * V = \left(\frac{\pi}{4} D^2\right) 83.5 \left(\frac{D}{4}\right)^{2/3} \cdot S^{1/2}$$

$$\boxed{Q = 26.02\, D^{8/3} S^{1/2}}$$

(vi) William-Hazen's Formula: For flow under pressure for designing water pipes.

V=0.85 C R0.63 S0.54

C value depends on the type of pipe material.

Note: Apart from the above formulae; Nomograms, Tables, Charts are also available for designing sewers.

SEWER DESIGN

Hydraulic Elements of Circular Sewers

Advantages of Circular Sewer Sections:

(i) Easy to manufacture.

(ii) Efficient Section: A circular section gives the highest H.M.D. (Hydraulic Mean Depth) when running full (or) half full. When depth is more, velocity and discharge will be high.

(iii) It is the most economical section since it utilises minimum quantities of material.

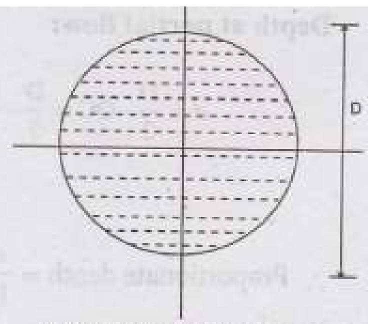
(iv) Circular section have uniform curvature all around and it offers less opportunities for deposits.

Sewers should run atleast half full.

$$\boxed{\text{Area of cross-section, } A = \frac{\pi}{4} D^2}$$

Wetted perimeter, $P = \pi D$

Hydraulic Mean Depth, $R = \frac{A}{P} = \frac{\pi/4 D^2}{\pi D} = \frac{D}{4}$



D = Internal Diameter of circular sewer

Hydraulic Elements of Standard Form:

a) off Sewer running full:

Area of crown portion = 1.57 b2

Area of central portion = 2.80 b2

Area of invert portion = 0.23 b2

Total Area = = 4.6 b2

Similarly, Total Perimeter = 7.82b

R=H.M.D. = 0.58b

b) Sewer running 2/3rd full:

Total area = 3.03b2

Area of central portion = 2.80b2

Area of invert portion = 0.23b2

Total perimeter = 4.68b.

H.M.D= R = 0.64b.

c) Sewer running half-full and one-third full:

At running half full, R = 0.54b.

At running one-third full, R = 0.41b.

Hydraulic elements of the New Form:

a) Sewer running full:

Area of crown portion = 1.57 b2

Area of central portion = 2.86 b2

Area of invert portion = 0.03 b2

Total area = 4.46 b2

Perimeter = 7.82 b

H.M.D, R = 0.57 b.

b) Sewer running 2/3 rd full:

Area of central portion	$= 2.86b^2$
Area of invert portion	$= 0.03b^2$
Total Area	$= 2.89b^2$
Perimeter	$= 4.68b$
H.M.D, **R**	$= 0.62b.$

c) Section running one-third full:

R=0.38b

Hydraulically equivalent Circular Sewers:

• The design of egg-shaped sewers is complicated.

• The computations of various hydraulic elements (such as area, wetted perimeter, hydraulic mean depth, etc.) of egg-shaped sewers involves complicated mathematical calculations.

• Therefore while designing egg-shaped sewers, approximate diameter of hydraulically equivalent circular sewer is calculated first, with the same discharge (running full) and laid at same gradient, and then converted into dimensions of egg-shaped section.

Let D = Diameter of hydraulically equivalent circular section.

D0 = Top horizontal diameter of egg shaped section.

Roughly,

$$\boxed{D \approx 1.2\, D_0}$$

Table 4.2 : Comparison of $\frac{v}{V}$ in circular and ovoid sewers

d/D	$\frac{v}{V}$	$\frac{v}{V}$
	Circular Sewer	*Standard Ovoid Sewer*
0.25	0.701	0.698
0.20	0.615	0.627
0.15	0.517	0.544
0.10	0.401	0.440
0.05	0.257	0.295

Other Sewer Sections

In soft soils with difficulty of providing foundations for circular/ovoid sections,following shapes are used.

- Semi-elliptical
- Rectangular
- Horse-shoe
- U-shaped.
- Parabolic

Shapes of sewer Pipes

Sewers are generally circular pipes laid below ground level, slopping continuously towards the outfall. These are designed to flow under gravity. Shapes other than circular are also used.

Other shapes used for sewers are:

a. Standard Egg-shaped sewer

b. New egg-shaped sewer

c. Horse shoe shaped sewer

d. Parabolic shaped sewer

e. Semi-elliptical section

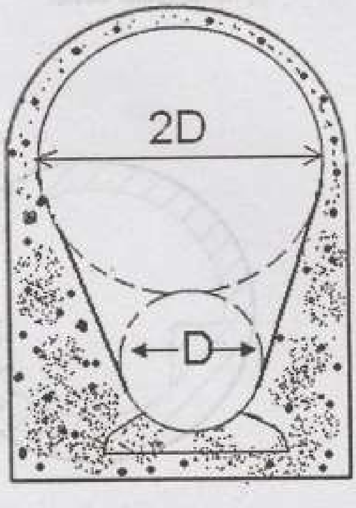
f. Rectangular shape section

g. U-shaped section

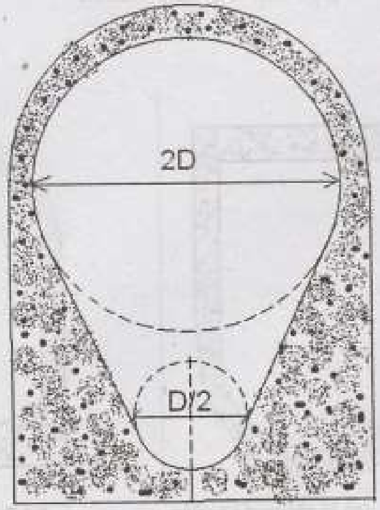
h. Semi-circular shaped sewer

i. Basket handled shape sewer

Standard egg-shaped sewers, also called as ovoid shaped sewer, and new or modified egg-shaped sewers are used in combined sewers. These sewers can generate self cleansing velocity during dry weather flow. Horse shoe shaped sewers and semi-circular sections are used for large sewers with heavy discharge such as trunk and outfall sewers. Rectangular or trapezoidal section is used for conveying storm water. U-shaped section is used for larger sewers and especially in open cuts. Other sections of the sewers have become absolute due to difficulty in construction on site and non availability of these shapes readily in market.

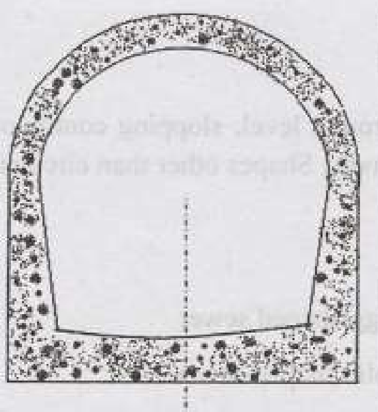


(a) Standard Egg Shaped Sewer

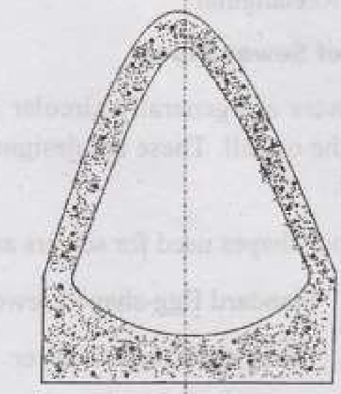


(b) New/ Modified Egg shaped Sewer

Fig. 4.9 (a), (b)

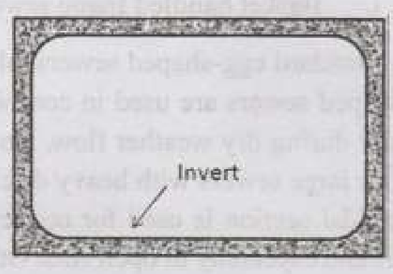


(c) Horse shoe sewer section

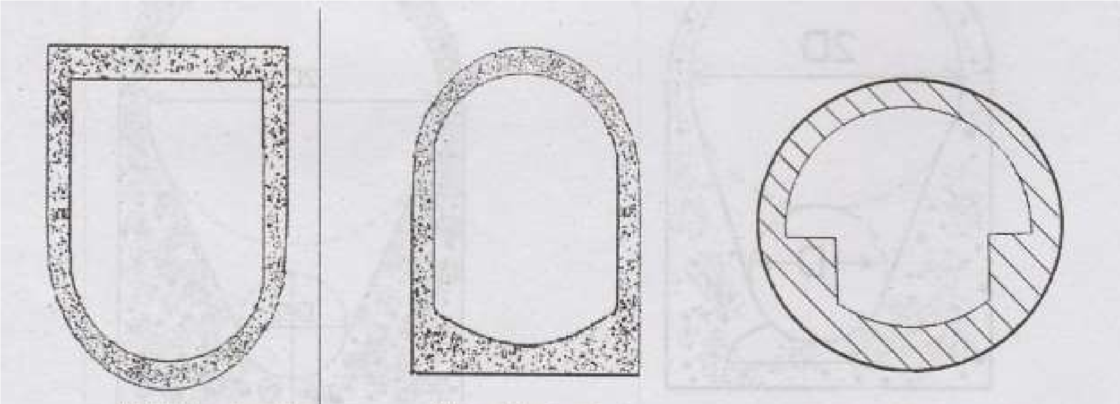


(d) Parabolic section

(e) Semi-elliptical section



(f) Rectangular Sewer



(g) U-shaped section (h) Semi-circular Section (i) Basket-Handle Section

Fig. 4.10 : Different shapes used for construction of sewer other than circular

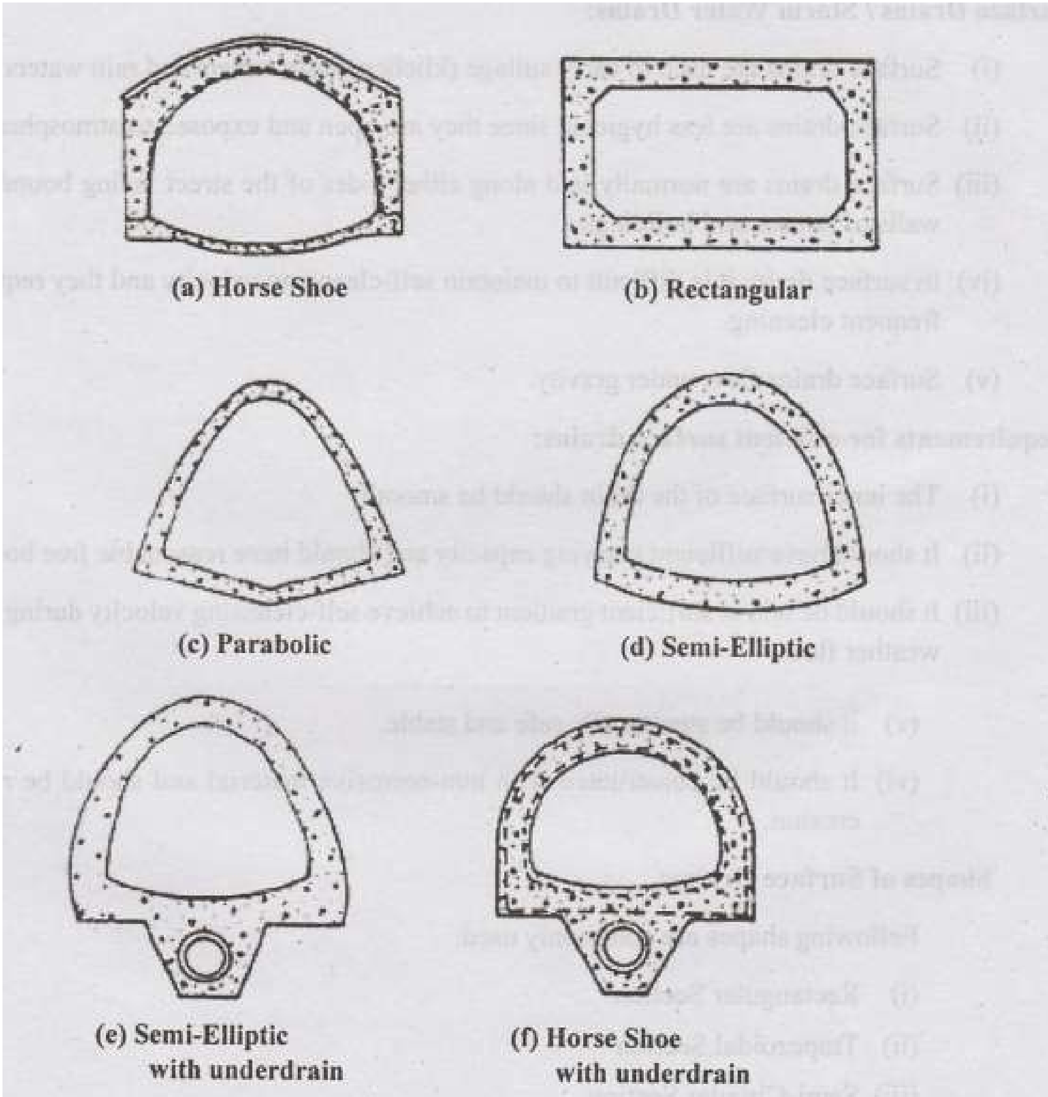
Shape of sewer depends on:

(i) Hydraulic (flow) conditions.

(ii) Construction Ease.

(iii) Foundation conditions.

(iv) Availability of space.



Figs. 4.11 : Other Sewer Sections

STORM DRAINAGE

Disadvantages of Combined Sewers: (Sewage + Drainage).

(i) Larger size of sewer section is required.

(ii) Hydraulic performance is unsatisfactory during Dry Weather Flow (DWF).

Hence, it is frequently preferred to carry the storm water through storm water drain.

Surface Drains / Storm Water Drains:

(i) Surface drains are used to carry sullage (kitchen waste water) and rain waters.

(ii) Surface drains are less hygienic since they are open and exposed to atmosphere.

(iii) Surface drains are normally laid along either sides of the street facing boundary walls of houses and buildings.

(iv) In surface drain, it is difficult to maintain self-cleansing velocity and they require frequent cleaning.

(v) Surface drains flow under gravity.

Requirements for efficient surface drains:

(i) The inner surface of the drain should be smooth.

(ii) It should have sufficient carrying capacity and should have reasonable free board.

(iii) It should be laid at sufficient gradient to achieve self-cleansing velocity during dry weather flow.

(iv) All the joints should be properly and neatly finished.

(v) It should be structurally safe and stable.

(vi) It should be constructed with non-corrosive material and should be resistant to erosion.

Shapes of Surface Drains:

Following shapes are commonly used:

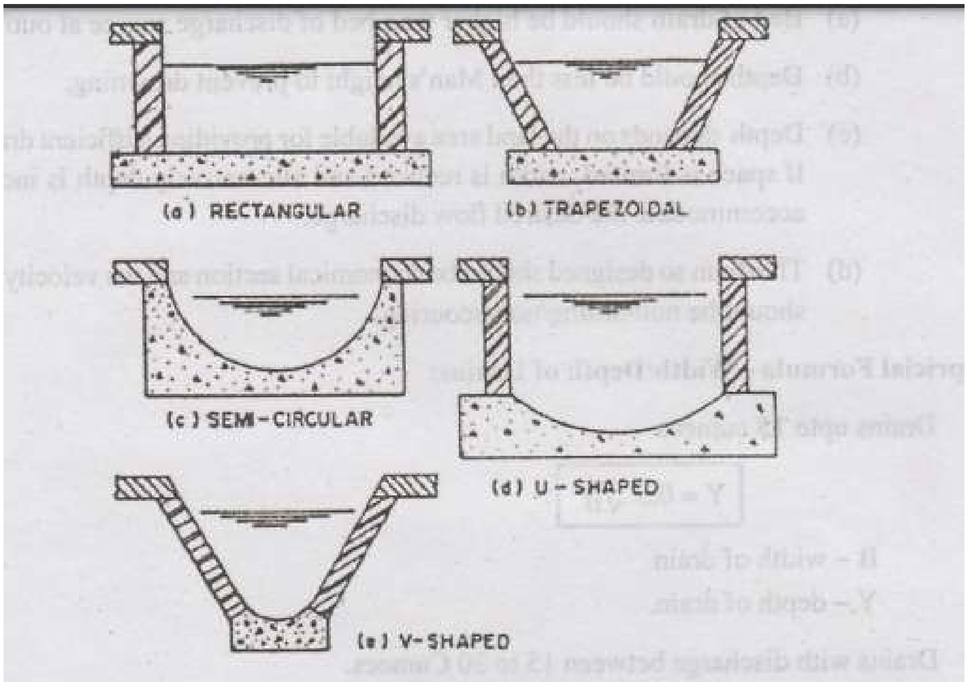
(i) Rectangular Section

(ii) Trapezoidal Section

(iii) Semi-Circular Section

(iv) U-section

(v) V-section.



Figs. 4.12 : Shapes of Surface Drains

Design of Drainage System

(i) Contour maps of the area is collected.

(ii) In the map, position of major/link drains and disposal source is marked to achieve gravity flow. Providing flat gradient is economical over the cost of pumping..

(iii) Alignment of drains-laterals, branches, mains is done.

(iv) Catchment area of each drain is marked.

(v) Based on population of catchment area, the peak discharge expected in each drain is calculated.

(vi) Information on underground structures (water lines, existing sewer lines, electric and telephone cables, gas lines, etc.,) location of streets, subsoil conditions, strata type, ground water level, fluctuations of the drain are assessed.

(vii) Longitudinal section of the entire drain line is drawn fixing FSL. The NSL (Natural Surface Level) of catchment area is checked with FSL of drain. NSL should be higher than FSL to prevent water logging.

(viii) The bed level (depth) of drain is fixed based on following criteria:

(a) Bed of drain should be higher than bed of discharge source at outfall point.

(b) Depth should be less than Man's height to prevent drowning.

(c) Depth depends on the land area available for providing sufficient drain width. If space is limited, width is reduced and alternatively depth is increased to accommodate the desired flow discharge.

(d) The drain so designed should be economical section and the velocity achieved should be non-silting/non-scouring.

Empricial Formula - Width/Depth of Drains:

(i) Drains upto 15 cumecs

$Y = 0.5 \sqrt{B}$

B-width of drain

Y - depth of drain.

(ii) Drains with discharge between 15 to 30 Cumecs.

Table 1.5

Discharge (Cumecs)	Depth Y(m)
15	1.7
30	1.8
75	2.3
150	2.6
300	3.0

(iii) CWC's recommendations (Central Water Commission).

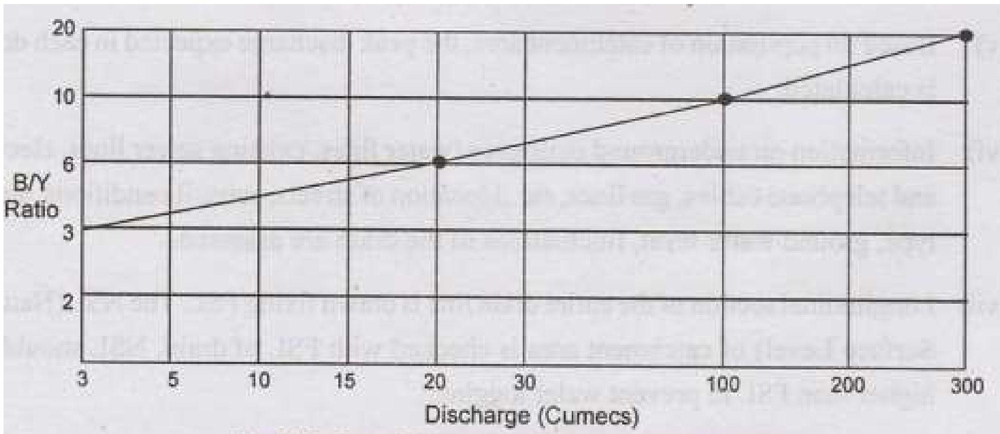


Fig. 4.13 : Central Water Commission Recommendation

Table 4.3 : Permissible Velocities in Drains

Type of Soil/Type of Surface	*Maximum Permissible Velocity (m/s)*
(a) Unlined Drains	
(1) Rock and gravel	1.5
(2) Murram, hard soil etc.	1.0 to 1.1
(3) Sandy loam, black cotton soil	0.6 to 0.9
(4) Very light loose sand to average sandy soil	0.3 to 0.6
(5) Ordinary soil	0.6 to 0.9
(b) Lined Drains	
(1) Stone pitched	1.5
(2) Burnt clay tile lined	1.8
(3) Cement concrete lined	2 to 2.5

STORM RUNOFF ESTIMATION

Peak run-off rate depends on.

❖ Type of precipitation.

❖ Intensity and duration of rainfall.

❖ Rainfall distribution.

❖ Soil moisture.

❖ Direction of storm/duration/storm frequency.

❖ Climatic conditions.

• Shape, size, type of catchment basin.

• Impermeability factor.

(a) Rational Formula:

❖ Assuming that if rain falls on an impervious surface at a constant rate, the resultant runoff from the surface would be equal to the rainfall.

Runoff rate = Rate of rainfall.

Time of Concentration:

Period after which the entire catchment area starts contributing to the runoff in drains.

Critical Rainfall Duration:

Maximum runoff obtained from rain having duration equal to the time of the concentration

Based on the basic principles, the rational formula was evolved by Fruhling, Kuichling lioz bied,menuM (S).

$$\boxed{Q_P = \left(\frac{1}{36}\right) k \cdot p_c \cdot A}$$

Qp → Peak rate of runoff in cumecs

K → Co-efficient of runoff

A → Catchment area in hectares

Pe → Critical rainfall intensity (cm/hr).

Co-efficient of Runoff (Impervious Factor)

❖ The co-efficient of runoff (k) is the impervious factor of runoff, representing the ratio of precipitation to runoff.

❖ The value of k increases as the impreviousness of the area increases.

k = Ratio of precipitation to runoff

❖ Value of k varies with the type of surface.

k=1 → Perfectly impervious surface.

[For parks, lawns, gardens, k = 0.05 -0.25

Wooden lands, k = 0.01 -0.20]

Average Impermeability Factor (I) (k):

$$K = I_{av} = \frac{A_1 I_1 + A_2 I_2 + ... + A_n Z_n}{A_1 + A_2 + ... + A_n} = \frac{\Sigma AI}{\Sigma A}$$

A1,A2, A3 → Area of different surfaces of catchment.

I1, I2, I3→ Corresponding impermeability factors for different surfaces.

PROBLEMS

1. The surface on which the rain fall occurs in a district is given below.

$$Q_p = C_2 M'^{\left[0.93-\left(\frac{1}{14}\right)\log M'\right]}$$

The total area of the district is 36 hectares and the maximum rain intensity is 5 cm/hr.

Determine

i) Co-efficient of runoff.

ii) Total runoff for district.

Solution: Runoff ratio for entire area.

$$K = \frac{\Sigma KA}{\Sigma A} = \frac{K_1A_1 + K_2A_2 + K_2A_3 + \ldots + K_nA_n}{A_1 + A_2 + A_3 + \ldots + A_n}$$

$$K_1A_1 = \left[\frac{20}{100} \times 0.9\right] A = 0.18\,A$$

$$K_2A_2 = \left[\frac{20}{100} \times 0.85\right] A = 0.17\,A$$

$$K_3A_3 = \left[\frac{5}{100} \times 0.80\right] A = 0.04\,A$$

$$K_4A_4 = \left[\frac{15}{100} \times 0.4\right] A = 0.06\,A$$

$$K_5A_5 = \left[\frac{35}{100} \times 0.1\right] A = 0.035\,A$$

$$K_6A_6 = \left[\frac{5}{100} \times 0.05\right] A = 0.025\,A$$

$$K = \frac{K_1A_1 + K_2A_2 + K_3A_3 + K_4A_4 + K_5A_5 + + K_6A_6}{A}$$

$$= \frac{(0.18 + 0.17 + 0.04 + 0.06 + 0.035 + 0.025)A}{A}$$

$$\boxed{K = 0.4875.}$$

Rational Formula:

$$Q_p = \frac{1}{36} k \cdot p_c \cdot A$$

$p_c = 5$ cm/hr; $A = 36$ hectares.

$$= \frac{1}{36} \times 0.4875 \times 5 \times 36$$

$$\boxed{Q_p = 2.44 \text{ cumecs.}}$$

2. In the same problem, if the time of concentration for the area is 30 minutes, find the maximum runoff (if maximum rain intensity is not given). Also use formula, R=900/(t+60).

Solution: Time of concentration is given as 30 min.

Rain intensity = $p_c = R = \dfrac{900}{t+60}$ mm/hr (using given formula)

$$p_c = \frac{900}{30+60} = 10 \text{ mm/hr} = 1 \text{ cm/hr.}$$

$$p_c = 1 \text{ cm/hr}$$

Rational formula for peak discharge,

$$Q_p = \frac{1}{36} k \cdot p_c \cdot A$$

$$= \frac{1}{36} \times 0.4875 \times 1 \times 36$$

Maximum runoff = Qp = 0.4875 cumecs.

3. The surface water from airport road is drained to the longitudinal side drain from across one half of a bituminous pavement suface of total width 7.0 m, shoulder and adjoining land of width 8.0 m on one side of the drain. On the other side of the drain, water flows across from reserve land with average turf and 2% cross slope towards the side drain, the width of this strip of land being 25 m. The inlet time is 10 min. The runoff coefficients of the pavement, shoulder and reserve land (turf) are 0.8, 0.25 and 0.35 respectively. The length of the land parallel to road from where water is expected to flow to side drain is 400 m.

Estimate the quantity of runoff flowing in the drain assuming 10 year frequency. The side drain will pass through clayey soil with allowable velocity of flow as 1.33 m/s.

Intensity Duration Chart-10 Year Frequency	
Duration (mins)	Intensity (mm/hr)
5	160
10	150
$\boxed{15}$	$\boxed{125}$
20	110

$$K=\frac{\Sigma KA}{\Sigma A}=\frac{K_1A_1+K_2A_2+K_2A_3+...+K_nA_n}{A_1+A_2+A_3+...+A_n}$$

$$K_1A_1=\left[\frac{20}{100}\times 0.9\right]A=0.18A$$

$$K_2A_2=\left[\frac{20}{100}\times 0.85\right]A=0.17A$$

$$K_3A_3=\left[\frac{5}{100}\times 0.80\right]A=0.04A$$

$$K_4A_4=\left[\frac{15}{100}\times 0.4\right]A=0.06A$$

$$K_5A_5=\left[\frac{35}{100}\times 0.1\right]A=0.035A$$

$$K_6A_6=\left[\frac{5}{100}\times 0.05\right]A=0.025A$$

$$K=\frac{K_1A_1+K_2A_2+K_3A_3+K_4A_4+K_5A_5++K_6A_6}{A}$$

$$=\frac{(0.18+0.17+0.04+0.06+0.035+0.025)A}{A}$$

$$\boxed{K=0.4875.}$$

4. In problem 1.1, if the density of population is 250 per hectare and the rate of water supplied per day is 225 Iped. Calculate the quantity of:

a) Sewage flow for which the sewers of a separate system, should be designed?

b) Storm water for which the sewers of a partially separate system are designed?

Solution:

i) Sewage Flow - Separate system.

Population Density = 250 persons per hectare.

Total population = 250/hectare × 36 hectare

= 9000.

Water supply = 225 lpcd

Rate of water supply = Per capita water demand x Population

= 225 lpcd × 9000

= 202500 l/d

= 2025 m3/d= 2025 24×60×60 m3/s

= 0.0234 m3/s.

Assuming the sewage discharge is 0.8 times the water supplied.

Rate of sewage produced (Average Flow) = 0.8 x rate of water supplied

= 0.8 x 0.0234 m3/s.

= 0.0187 m3/s.

Now assuming the peak flow as three time the average flow

Peak rate of sewage flow= 3 x Average flow

= 3 x 0.0187 = 0.056 m3/s.

= 0.056 cumecs.

ii) Partially Separate System

In case of partially separate system, the storm water from roofs and paved yards of houses will be allowed to enter the sewers.

Surface	Area	k
Roof	20%	0.90
Paved Yards	5%	0.80

$p_c = 5$ cm/hr
Area = 36 hectares
(refer problem 1.1)

SEWER APPURTENANCES

Sewer appurtenances are those structures which are constructed at suitable intervals along a sewerage system, which helps in efficient operation and maintenance. These include:

(1) Manholes.

(2) Drop Manholes

(3) Lampholes

(4) Clean-outs

(5) Street inlets (Gullies)

(6) Catch Basins

(7) Flushing Tanks

(8) Grease and Oil Traps

(9) Inverted Siphons

(10) Storm Regulators.

CORROSION IN SEWERS

Bacteria in the slime under flowing sewage convert sulphates in the sewage into sulphides. Sulphides in the liquid make their way to the surface of the sewage and released into the sewer atmosphere as hydrogen sulphide (H,S) gas.

H2S gas in atmosphere makes contact with slime in the crown of the sewer, which contains more bacteria. Bacterial action converts, H,S gas to sulphuric acid which causes corrosion in the crown of the pipe and this corrosion is also called crown corrosion. If pipe material is of corrodible nature sulphuric acid attacks the pipe material and causing ultimate failure.

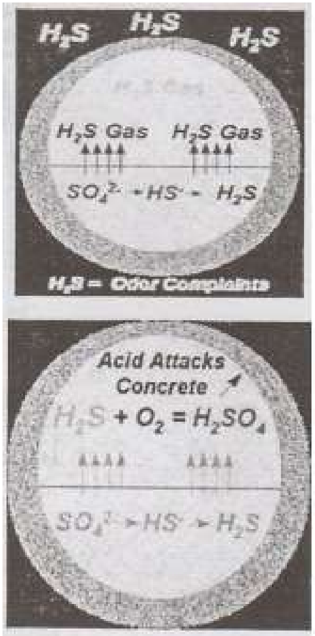


Fig. 4.27 : Corrosion Mechanism in Sewers

UNDERSTANDING CONCRETE SEWER PIPE CORROSION

Brief History

Concrete sewer pipe corrosion was first observed towards the end of the 19th century when it was rightly concluded that sulphuric acid was the corrosive agent however it wasn't until the 1940's that the biological nature of the concrete corrosion process was established through work undertaken in Australia and the USA when the bacterium "Thiobacillus concretivorous", (later renamed Acidithiobacillus Thiooxidans) was identified amongst the acidic corrosion products. Today we know that there are many bacterial and fungal species involved in the concrete sewer pipe corrosion cycle.

Microbial induced corrosion (MIC) of concrete sewers was not regarded as a significant issue until the 1980's when corrosion rates in sewers increased significantly in the USA, Europe and Australia. At this time tighter controls placed on industrial wastewaters to be discharged to the sewer system (e.g. the US Clean Water Act) led to significantly lower levels of biologically toxic metals such as lead, mercury and arsenic in the sewer system and as a consequence bacterial levels (and consequently MIC) increased dramatically.

Modern day increases in corrosion activity are also linked to:

• increased sewage temperature, (due to increasing use of hot water in domestic situations)

• increased use of sulphate containing detergents

• increase in sewer line lengths (and hence sewage residence times) om sd reinforced concrete sewer pipe is currently considered one of the most serious egunotand costly problems currently affecting the world's sewer infrastructure with the global repair bill for

MIC corrosion of sewer piping estimated to be in the order of billions of dollars per year. on pri prihub noizol

jonsini od bollment

nolls Concrete sewer pipe is corroded by acids produced in the sewer from chemical and microbial processes. Microbial induced corrosion (MIC) however is responsible for most of the corrosion that takes place.

The basic sewer processes that drive concrete corrosion activity are illustrated in Fig. 4.28. The corrosion cycle begins in the wastewater stream. Colonies of anaerobic sulphate reducing bacteria (SRB) active in biofilm layers that line the submerged sewer walls reduce sulphates and oxidise biodegradable organic carbon producing hydrogen sulphide and carbon dioxide:

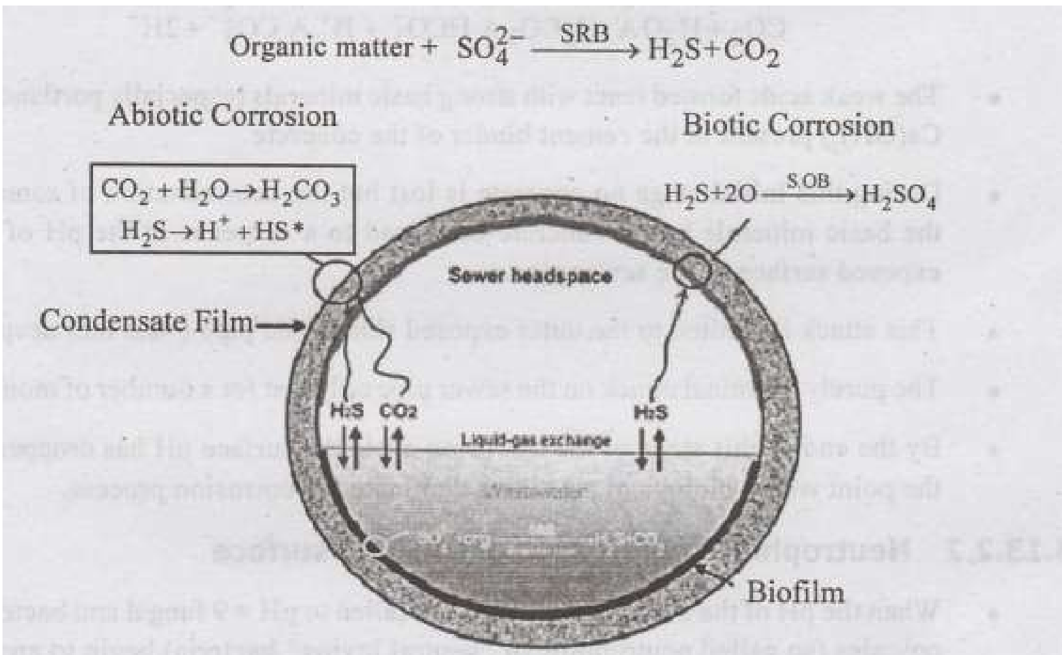


Fig. 4.28: Schematic of sewer processes driving corrosion

1 Chemical corrosion during the initial months

• When a concrete sewer pipe is first manufactured and installed the interior bas loin surface of the pipe is too alkaline (pH>10.5) for bacterial or fungal colonisation admol to take place.

• Under these circumstances only the chemical corrosion of the pipe is possible.

• H2S and CO2 dissolve in the concrete pore water to form weak acids:

$$H_2S\ddot{A}\ HS^- + H^+$$

$$CO_2+H_2O\ddot{A}\ \ H_2CO_3\ddot{A}\ HCO_3^- + H^+\ \ddot{A}\ CO_3^{2-}+2H^+$$

2 Neutrophilic colonisation of the pipe surface

• When the pH of the surface of the pipe has fallen to pH = 9 fungal and bacterial colonies (so called neutrophilic or “neutral loving” bacteria) begin to appear on the pipe surface.

• As the surface of the pipe becomes more acidic successive waves of bacteria more suited to lower pH conditions will dominate the pipe surface.

• Neutrophilic bacteria produce carboxylic acids as well as sulphuric acid from the oxidation of a number of sulphur species present on the pipe surface.

• The production of these acids acts to further lower the pH of the sewer pipe surface but no measurable loss of mass has as yet occurred.

3 Sound concrete loss begins.

• When the pH of the surface of the sewer pipe falls to pH 6 significant conversion of sound concrete to corroded product (mostly gypsum) begins.

• The time taken to reach this point in the corrosion cycle varies from site to site (depending on the environmental conditions present) but will generally be between 6 months to 2 years from the date of installation.

• Once mass loss begins the rate at which concrete is lost per year remains constant for the remainder of the pipe’s service (if sewer conditions remain constant).

• The rate at which concrete is lost however varies from site to site and is dependent on a number of environmental factors.

• The surface pH will continue to fall after mass loss begins but the rate at which it falls slows.

• As sound concrete loss continues a layer of corroded product builds on the pipe surface however this layer does not affect level of corrosion activity and the rate of corrosion remains constant.

• When the amount of concrete lost over time is plotted the corrosion function takes the following general form:

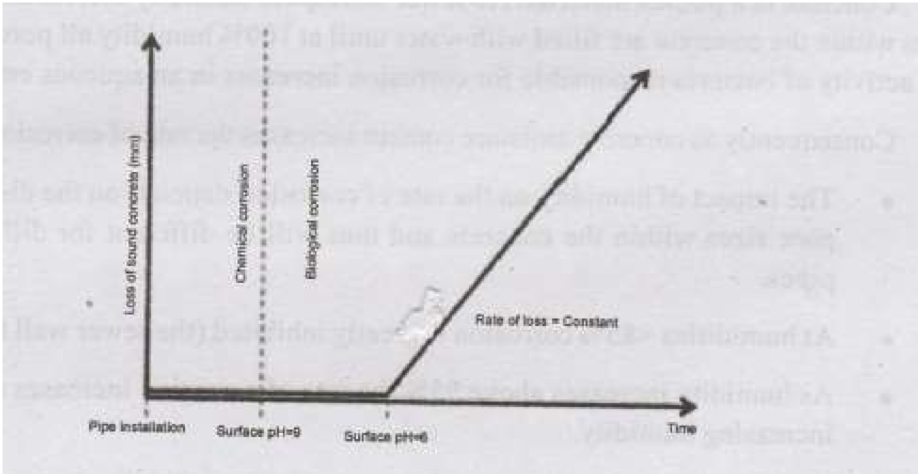


Fig. 4.29: The corrosion of concrete sewer pipe over time.

Factors affecting the rate of concrete sewer pipe corrosion

The rate at which sound concrete is corroded (once the surface pH <6) varies from site to site depending on the nature of the local sewer environment.

SEWAGE PUMPING

Necessity of Pumping Sewage

(i) For lifting sewage from low lying areas [sewers run at higher elevation than the sources of sewage generation].

(ii) In flat terrains, laying of sewers at designed gradient requires large excavation and is expensive. To reduce the excavation cost, pumping is done at suitable intervals. aliq ni

(iii) Pumping is resorted to when outfall sewer is lower than the entrance of treatment works or receiving water bodies.

(iv) For lifting sewage from basements of commercial buildings (since street sewers are higher than basement level of buildings).

(v) Instead of driving tunnel through ridges for sewer line, its economical to pump sewage into sewers laid across the slope of ridges.

Problems in Pumping Sewage

(i) Sewage has foul characteristics.

(ii) Suspended and floating matter in sewage clogs the pumps.

(iii) Organic and inorganic waste in sewage cause corrosion and erosion of pump parts and reduce their life.

(iv) Disease producing organisms (pathogens) in sewage cause health hazard to working personnel.

(v) Higher reliability pumps are required to prevent flooding nuisance.

Requirements of Sewage Lifting Pumps

a) Pump Capacity.

❖ Must be able to handle peak flows.

❖ Two or more pumps and power sources are required.

(b) Clogging Aspects.

❖ Special pumps which do not clog due to the floating and suspended solids in sewage are used.

❖ Pumps should be accessible for cleaning and removal of obstructions.

Types of Pumps

(1) Centrifugal Pumps.

(2) Reciprocating Pumps.

(3) Pneumatic Ejectors or Air Pressure Pumps.

Advantages:

(i) Automatic operation and require least supervision.

(ii) Used where centrifugal pumps get clogged.

(iii) Only few parts come in contact with sewage.

(iv) Ejectors do not get clogged.

(v) Economical where smaller quantities of sewage are required to be lifted. V bus V

Disadvantage:

(i) Low efficiency - 15%.

PLUMBING SYSTEM FOR DRAINAGE

1. Single Stack System:

2. One Pipe System.

3. Partially Ventilated Single Stack System.

4. Two Pipe System.

1. Single Stack System:

❖ System in which the waste matter from bathrooms, sinks etc. as well as foul matter from the water closets are discharged in one single pipe called the Soil and Waste Pipe(SWP)

❖ No separate vent pipe is provided.

❖ Effective only if the traps are filled with water seal of depth not less than 75 mm.

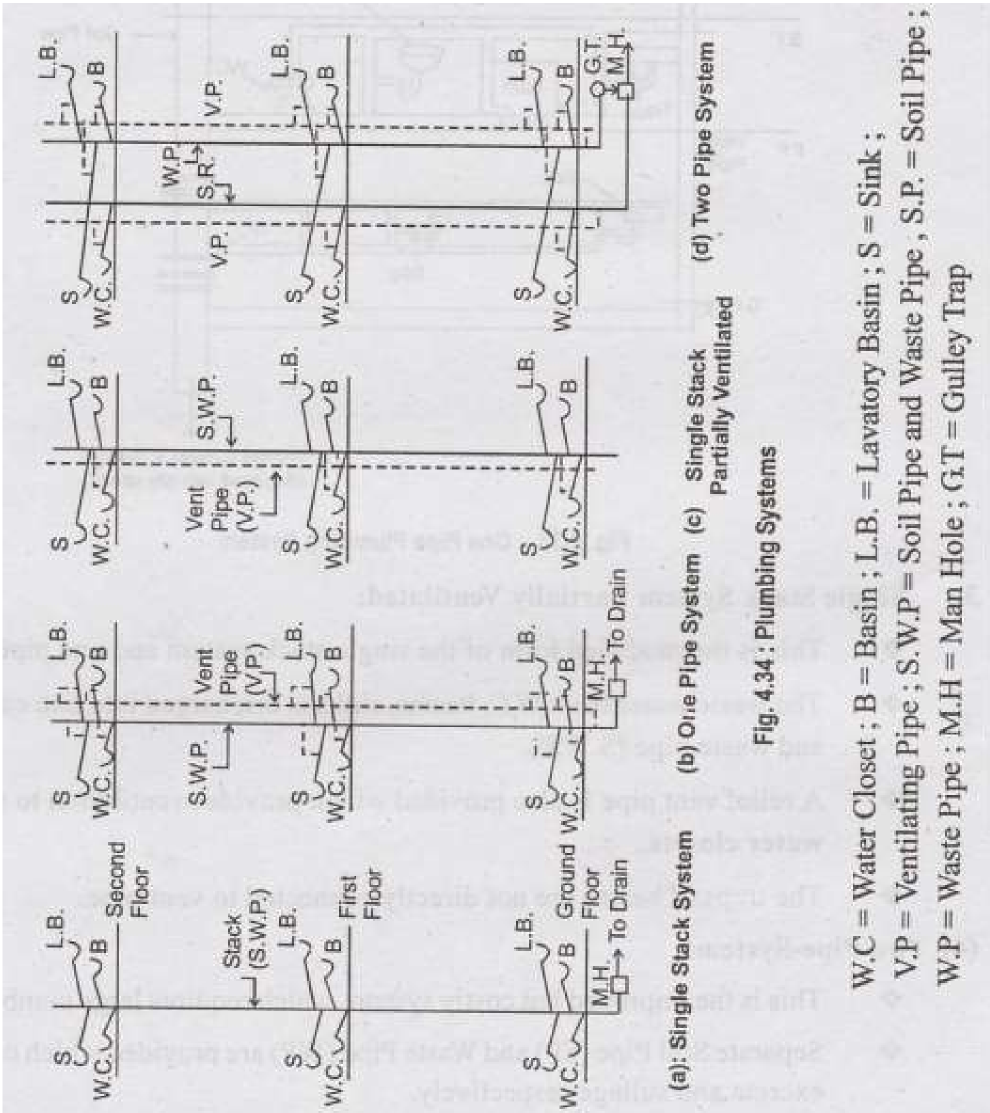


Fig. 4.34 : Plumbing Systems

W.C = Water Closet ; B = Basin ; L.B. = Lavatory Basin ; S = Sink ;
V.P = Ventilating Pipe ; S.W.P = Soil Pipe and Waste Pipe , S.P. = Soil Pipe ;
W.P = Waste Pipe ; M.H = Man Hole ; G.T = Gulley Trap

2. One Pipe System: (Costlier than Single Stack System)

❖ One common Soil and Waste Pipe (SWP) connects different floors and carries mo both human excreta and sullage.

❖ A separate vent pipe is also provided.

❖ Traps of all water closets, basins etc. are completely ventilated. aciq pigme

❖ Cowl is provided at the top of SWP for ventilation.

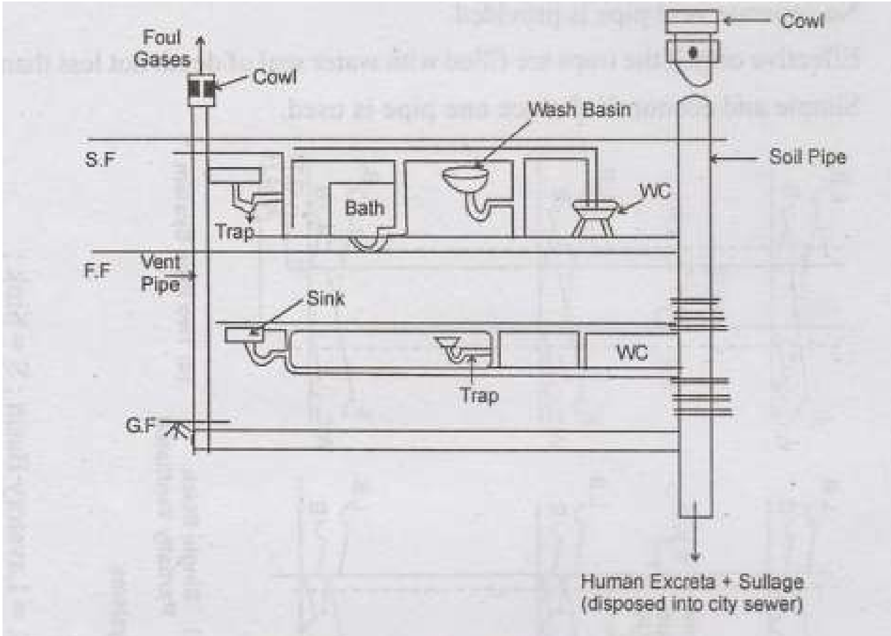


Fig. 4.35 : One Pipe Plumbing System

3. Single Stack System Partially Ventilated:

❖ This is the modified form of the single stack system and one pipe system.

❖ The waste water from W.C, basins, sinks is discharged into one common soil and waste pipe (S.W.P).

❖ A relief vent pipe is also provided which provides ventilation to the traps of water closets.

❖ The traps of basins are not directly connected to vent pipe.

(4) Two Pipe-System:

❖ This is the improved but costly system, which requires large number of pipes.

❖ Separate Soil Pipe (SP) and Waste Pipe (WP) are provided which carry human excreta and sullage respectively.

❖ Water closet is connected to Soil Pipe(S.P)

❖ Bathrooms, sinks, lavotary basins are connected to waste pipes (WP) which are connected to drains.

❖ All the traps are ventilated by separate ventilation pipes.

❖ One ventilation pipe provided alongwith soil pipe and another ventilation pipe for the waste pipe. A total of 4 pipes - one soil pipe, one waste pipe aswinie and two ventilation pipes are provided.

Choice or Selection of Plumbing Systems

To Two Pipe Systems

❖ Efficient for multi-storeyed buildings

❖ Requires minimum use of traps.

❖ But, large number of pipes makes the system costly.

❖ Difficulty in accommodating pipes in buildings.

One Pipe System:

❖ Economical.

❖ Easy to accommodate.

❖ But require ventilation, water seals and proper connections.

❖ In multistoreyed buildings, it requires lavotary blocks to be placed one above the other.

Water Supply And Wastewater Engineering: Unit IV: Planning And Design Of Sewerage System: Two Marks Questions And Answers

TWO MARK QUESTION AND ANSWERS

1. What is sewage?

Wastes are mixed with sufficient quantity of water & carried through closed conduits under the conditions of gravity flow. This mixture of water and waste products popularly called sewage

2. What are the sources of sewage?

Domestic sewage: Originates from urinals, latrines, bathrooms, kitchen sinks, wash basins of residential, commercial or institutional buildings

Industrial sewage: Originates from industrial processes such as dyeing, paper making, brewing etc

Strom sewage (or) storm drainage: Originates from rain storm

3. What are the two types of sewage system?

The two types of sewage system are,

(a) Combined system: When the drainage is taken with the sewage then it is called as combined system

(b) Separate system: When the drainage and sewage are taken independently of each through two different sets of sewage is called as separate system.

4. Define time of concentration?

The period after which the entire area will start contributing to the runoff is called time of concentration.

5. List the components of sewerage system?

The components of sewerage system are

(a) House sewers

(b) Lateral sewers

(c) Branch sewers

(d) Main sewers

(e) Outfall sewers

(f) Man holes.

6. What is peak drainage discharge?

The method estimating the maximum rate of storm runoff is called as peak drainage discharge.

7. What is meant by biodegradable organic matter?

The organic matters is decomposed by bacteria under biological action is called biodegradable organic matter

8. What are the various tests for finding the quality of sewage?

• Turbidity test

• Colour test

• Tuohoq test

• Odour test

9. What is meant by relative stability of a sewage effluent?

The relative stability of a sewage effluent is the ratio of oxygen available in the effluent to the total oxygen required to satisfy its first stage BOD demand

10. Differentiate B.O.D & C.O.D

B.O.D (Bio-chemical Oxygen Demand) directly gives the amount of biologically active organic matter (Biodegradable) present in sewage

C.O.D (Chemical Oxygen Demand) is a measure of total organic matter (Biodegradable as well as non- Biodegradable)

11. The average sewage flow from a city is 80 × 10° l/d. If the average 5 day B.O.D is 285 mg/l, compute the total daily 5 day oxygen demand in Kg, and the population equivalent of the sewage. Assume per capita B.O.D of sewage per day = 75g.

Quantity of sewage flowing per day : 80 × 106 litres

Average 5 day B.O.D = 285mg

Total daily 5 day oxygen demand = 285 × (80 × 106) mg = 22,800 Kg

12. What are the methods of population forecasting?

(a) Arithmetic increase method

(b) Geometric increase method

(c) Method of varying increment (or) Incremental increase method

(d) Decreasing rate of growth method

(e) Simple graphical method

(f) Comparative graphical method

(g) Master plan method (or) zoning method

(h) The logistic curve method

13. Define design period?

The future period for which a provision is mode in the water supply scheme is known as design period.

14. What are the factors governing the design period?

The factors governing design period are,

(a) Design period should not exceed the life period of the structure.

(b) If the funds are not in a sufficient, the design period as to be decreased.

(c) The rate of interest on borrowing and the additional money invested.

15. What is critical rainfall duration?

Maximum runoff will be obtained from the rain having duration equal to the time of concentration. This is called critical rainfall duration

16. What is intensity of rainfall?

The intensity of a rain is the rate at which it is falling, which it is falling, and it is ex is expressed in cm/hr

17. What are the Physical Characteristics of wastewater?

• Carbonaceous substrates

• Nitrogen

• Phosphorous

• Chlorides

• Total and volatile suspended solids (TSS and VSS)

• Toxic metals and compounds

19. What is BOD (Biochemical oxygen demand?)

Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period

20. What is COD (Chemical oxygen demand?)

Chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water. It is expressed in milligrams per liter (mg/L).

21. Mention some shapes of sewer pipes

- Circular shape
- Egg shape
- Horse shoe shape
- Elliptical shape
- Parabolic shape
- Rectangular shape

22. What are the forces acting on sewer pipes?

- Internal pressure of sewage.
- Temperature stress
- Pressure due to external loads
- Flexural stress

23. What are the materials used for constructing sewer pipes?

- Vitrified clay
- Asbestos cement
- Cement concrete
- Cast iron

24. Give some qualities of the good sewer pipes.

- Resistance to corrosion
- Resistance to abrasion

- Strength and durability.
- Light weight
- Economy and cost

25. What are the tests conducted in sewer pipes after laying?

- Test for leakage (water test)
- Test for straightness of alignment and obstruction

26. Define sewer appurtenances.

Sewer appurtenances are those structures which are constructed at suitable interval along a sewerage system and help in its efficient operation and maintenance.

27. Mention the classification of manholes.

- Shallow manholes
- Normal manholes
- Deep manholes

28. What is meant by catch basins?

Catch basins are nothing but street inlets provided with additional small setting basins for avoiding the entry of the particles like grit, sand, debris in to the sewer pipes

29. Define inverted siphons

Inverted siphon is defined as the sewer section constructed lower than the adjacent sewer section and it runs full under gravity with pressure greater than the atmosphere

30. What are are the various methods of ventilation for sewers?

- Use of ventilating columns
- Use of ventilating manhole covers
- Proper design of sewers
- Use of mechanical devices

31. What are the different types of pumps used commonly for pumping the sewage?

• Centrifugal pump

• Reciprocating pump

• Pneumatic ejectors (or) Air pressure pumps

32. What is Small Bore Sewer?

The Small Bore Sewer is a watertight small diameter wastewater collection system that provides servicing with superior operational and environmental performance at a significantly lower cost as compared to historic gravity sewers

33. Write some Construction Benefits of Small Bore Sewer.

• Overall system is flexible, modular and adaptable.

• Shallow gradient piping installations eliminate need for heavy equipment - local manpower and hand tools can be used for trenching.

• Piping is not sensitive to curvilinear alignment, inflective gradients or sharp slope changes

34. Write some Environmental Benefits of Small Bore Sewer.

• 2 x reduction of greenhouse gases through methane capture when compared to equivalent carbon dioxide gas impact

• Conveyance of methane for reuse in electricity generation

• Sealed system means zero groundwater infiltration and zero sewage seepage

35. How to Test leakage in sewer pipes?

The ends of the sewer is plugged, the water is now filled in the manhole at the upper end and is allowed to flow through the sewer line. The depth of the water in the man hole is maintained to the testing head of about 1.5m. The sewer line is watched by moving along the trench.

36. How to Test straightness of alignment in sewer pipes?

The straightness of alignment in sewer pipes can be tested by placing a mirror at one end of the sewer line and lamp at the other end. If the pipe line is straight, the full circle of the light will be observed.

37. Explain One pipe system in sewerage?

The pipe of waste water from sinks, baths and wash basins and branches of soil pipes is connected to one main pipe. This main pipe is directly connected to sewerage system. Gulley (gutter) traps and waste pipes are completely distributed but all traps of water closets, basins, etc. are completely ventilated to preserve water seal.

38. Explain Two pipe systems in sewerage?

Soil and waste pipes are distinct and separate. The soil pipes are connected to sewer directly whereas waste pipes are connected through a trapped gulley (gutter). All traps of all appliances are completely ventilated.

39. What are the classifications of manhole?

• Shallow manhole

• Normal manhole

• Deep manhole

40. What are the component parts of Manhole?

• Access Shaft

• Working chamber

• The Benching (i.e) the bottom or invert portion of manhole

• The sidewalls

• Steps or ladders

• Cover and Frame

UNIT - V

SEWAGE TREATMENT AND DISPOSAL

OBJECTIVES (OR) NEED FOR WASTEWATER TREATMENT

(i) To remove solids in wastewater.

(ii) To prevent water pollution.

(iii) To prevent environmental degradation.

(iv) To avoid damage to soil structure.

(v) To minimize the discharge of wastewater into the environment.

Waste water treatment is a combination of physical, chemical and biological processes/ operations that can reduce the objectionable properties of waste and render it safe.

SELECTION OF TREATMENT PROCESS

Parameters to be considered are:

(i) Quantity/Volume of waste water to be treated.

(ii) Quality/Characteristics of waste water to be treated.

(iii) Effluent disposal standards.

(iv) Quality of treated waste water desired (Efficiency of treatment).

(v) Land required for installing treatment units.

(vi) Requirement of skilled labour for operation and maintenance.

(vii) Capital, operation and maintenance cost.

(viii) Economically viable, environment friendly and sustainable technology.

Table 5.1: Choice of unit operations/Processes for removal of major contaminants in waste water

Sl.No.	Contaminant	Unit Operations/Processes
1.	Suspended solids	(a) Plain sedimentation (b) Screening (c) Filtration.
2.	Biodegradable Organic matter	(a) Activated sludge process (b) Trickling filter (c) Lagoons.
3.	Pathogens	(a) Chlorination (b) Ozonisation.
4.	Nitrogen	(a) Nitrification and denitrification (b) Ammonia stripping (c) Ion exchange.
5.	Phosphorous	(a) Carbon adsorption (b) Bio-chemical phosphorous removal.
6.	Dissolved inorganic solids	(a) Ion exchange (b) Reverse osmosis (c) Electrodialysis.
7.	Heavy metals	(a) Ion exchange (b) Chemical precipitation.

ACTIVATED SLUDGE PROCESS AND EXTENDED AERATION SYSTEMS

• It is an aerobic process. It has two treatment units - an Aeration Tank followed by a Secondary Settling Tank.

• The organic solids in sewage are stabilised by excessive production of activated mass of aerobic microorganisms (called activated sludge).

• The sewage after sedimentation in the primary sedimentation tank enters the aeration tank where it is mixed with activated sludge (active microorganisms) and aerated (oxygen supply) for long hours.

• Aeration replenishes/increases dissolved oxygen (DO) level in sewage.

• The microorganisms utilise the organic waste in sewage as food and multiply in the presence of oxygen to synthesise numerous new microbial cells.

• The increase in microbial biomass helps in decomposition of organic waste in Ishotam I sewage.

• Later the biomass is settled in the secondary settling tank. The settled sludge has miw gnix active micro-organisms. (Activated Sludge)

• Some portion of the sludge is recycled back to aeration tank in order to maintain (high concentration of active microorganisms.

• The mixture of waste water and activated sludge in the aeration tank is called Mixed Liquor.

Process Steps:

1. Influent is either raw sewage or settled sewage from primary sedimentation tank.

2. Mixing of activated sludge with influent waste water to be treated (mixed liquor) in aeration tank.

3. Aeration and agitation of this mixed liquor in Aeration Tank for the required length of time (4 to 8 hours).

4. Multiplication of microbes by utilising organic waste in sewage and oxygen (D.O).

5. Settling/separation of activated sludge from the mixed liquor in the secondary settling process.

$$\text{Organic Waste (Sewage)} + O_2 + \text{Nutrients} \xrightarrow{\text{Micro-organisms}} CO_2 + H_2O + \text{Energy} + \text{Microorganisms (new cells synthesis)}$$

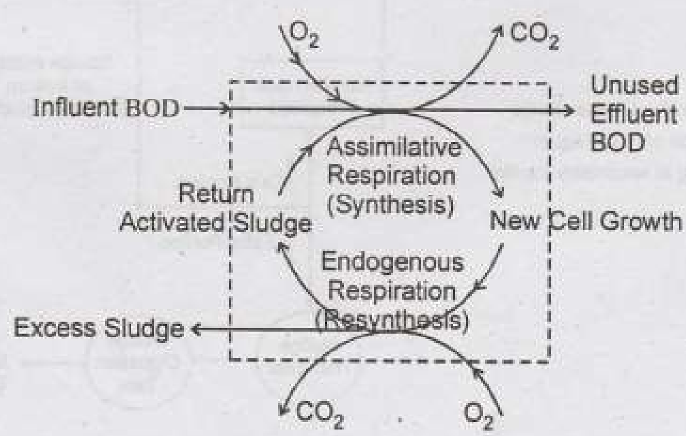


Fig. 5.1 : Biological Process in ASP

6. Recycle proper amount of activated sludge back to aeration tank for mixing with nistism on new b the new batch h of waste water (Sludge Recycling). to nothog emo2

7. Excess portion of sludge is disposed off after treatment. (Sludge Wasting)

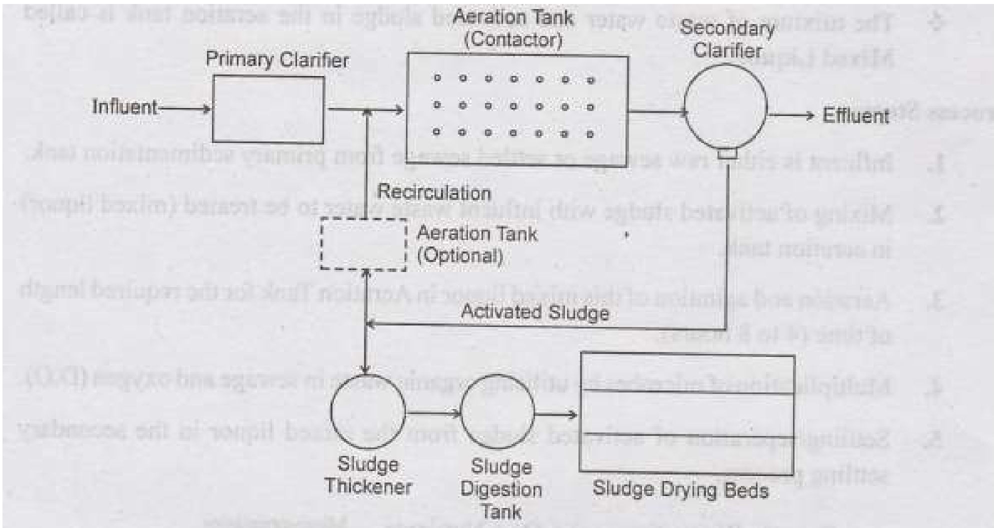


Fig. 5.2 : Flow Diagram of Activated Sludge Process

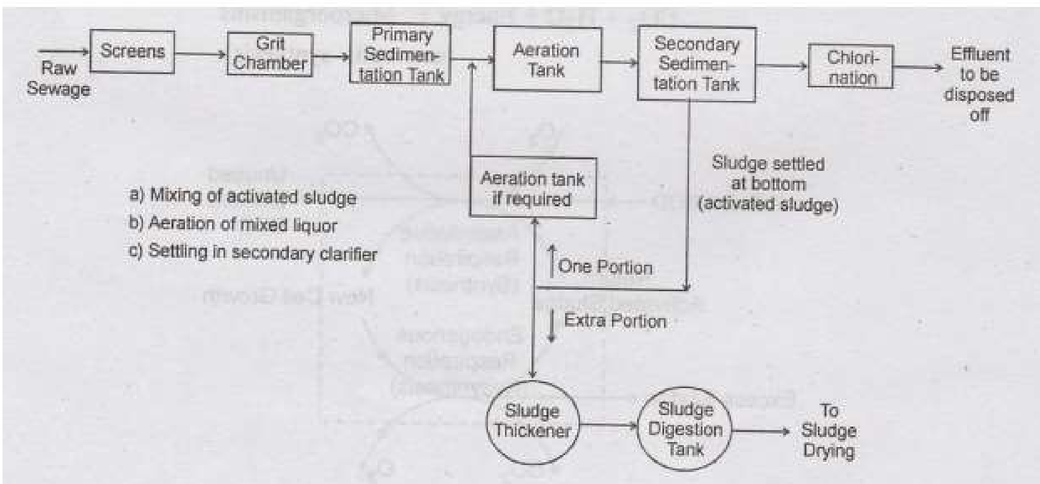


Fig. 5.3 : Flow Diagram for Conventional Activated Sludge Plant

8. Efficiency Effluent obtained from activated sludge plant is clear and of high quality with BOD removal efficiency of 80-95% and bacteria removal efficiency of 90-95%.

9. In ASP process, the following should be ensured:

(i) Ample supply of oxygen.

(ii) Intimate continuous mixing of sewage.

(iii) Ratio of volume of activated sludge added to volume of sewage being treated kept constant.

Operating Units of an ASP:

(i) Screen Chamber + Grit Chamber + Primary Settling Tank. Removal of settleable solids is helpful in preventing deposits on aeration devices.

(ii) Aeration Tank of ASP [Continuous Aeration].

• Normally rectangular tanks.

• Depth 3 to 4.5 m.

• Breadth 4 to 6 m.

• Length 20 to 200 m.

• Detention period 4 to 8 hours.

(iii) Secondary Settling Tank: To remove or settle the activated sludge from mixed liquor.

Methods of Aeration.

(i) Diffused air aeration/Air diffusion.

(ii) Mechanical aeration.

(iii) Combined diffused air and mechanical aeration.

(i) Diffused Aeration:

• Compressed air under pressure of 35 to 70 kN/m2 is introduced to aeration chamber through diffusion plates (Diffusers).

• Diffusers fixed at the bottom of aeration tank diffuse air in small bubbles to provide greater efficiency of aeration.

• Porous plates and porous tubes made of quartz (or) crystalline alumina are used as diffusers.

• Plates are square in shape with dimension of 30 cm x 30 cm and 25 mm thick. bluora gniwollot

• Tube diffusers are 60 cm long with internal diameter of 75 mm and thickness of wall equal to 15 mm.

• Types of Aeration Tanks → (i) Ridge and Furrow Type.

→ (ii) Spiral Flow Type.

• In Ridge and Furrow Type, the tank is formed into a succession of ridges and furrows and air is forced upwards through diffusers plates placed at the bottom of the furrows.

• In Spiral Flow type of aeration tank, air is introduced near the side of the tank in such a way that spiral flow results in the tank.

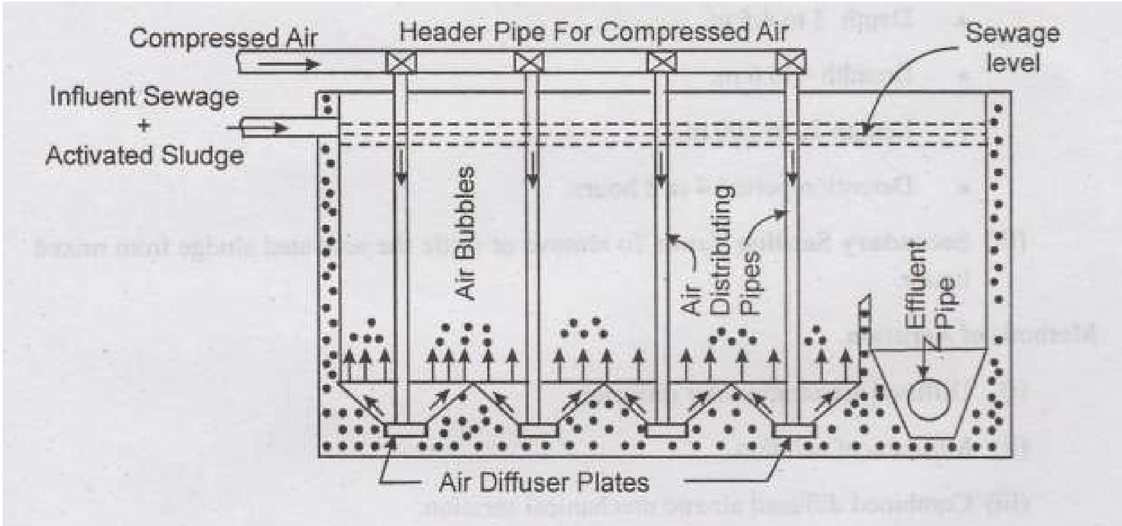


Fig. 5.4 : Ridge and Furrow Type Aeration Tank

(ii) Mechanical Aeration.

• Atmospheric air is used (instead of compressed air).

• Sewage is stirred up using mechanical devices like paddles (surface aerators).

• Surface of sewage is continuously changed by circulation of sewage from bottom to top and thereby introducing air from atmosphere into sewage.

• Only requirement is thorough agitation.

• Aeration period is 6 to 8 hours.

iii) Combined Aeration: (Dorr Aerator)

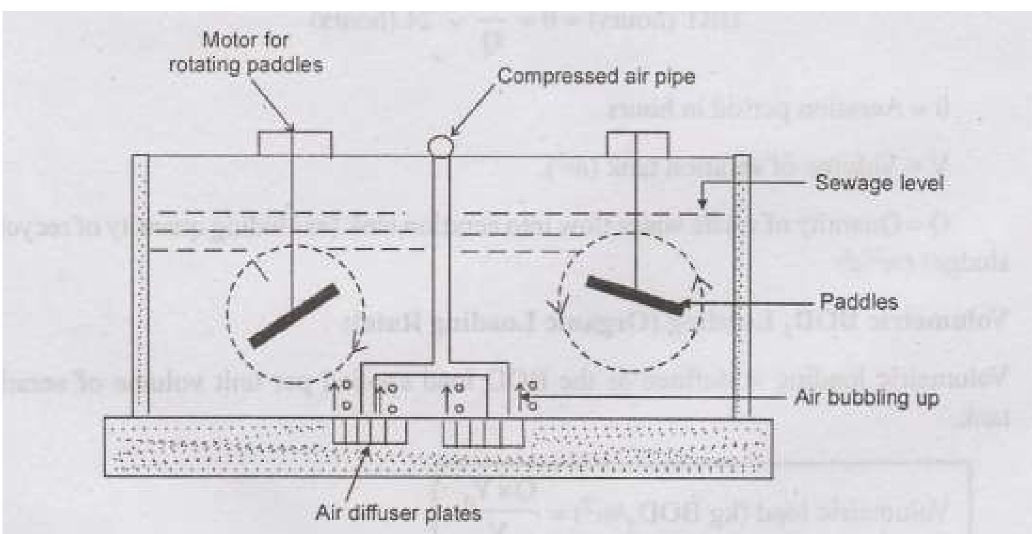


Fig. 5.9 : Dorr Aerator

• The diffused air aeration as well as the mechanical aeration are combined together in a single unit.

• A well known type is Dorr Aerator.

• Aeration of sewage is achieved by diffusing air through bottom diffuser plates as well as rotating paddles @ 10 to 12 r.p.m.

• Very efficient system with detention period of 5 hours.

Assumptions for design of conventional (plug flow) activated sludge plant

(i)	MLSS	= 1500 to 3000 mg/l
(ii)	MLVSS/MLSS	= 0.8
(iii)	F/M	= 0.4 to 0.2
(iv)	HRT (hours)	= 4 to 8
(v)	Volumetric loading (kg BOD_5/m^3)	= 0.3 to 0.7
(vi)	SRT (days)	= 5 to 15
(vii)	Return Sludge Ratio	r = 0.25 to 0.5 = 25% to 50%
(viii)	BOD removal efficiency	= 85 to 95%
(ix)	kg oxygen required per kg BOD_5 removal	= 0.8 to 1.1
(x)	Air required per kg BOD_5 (m^3)	= 40 to 100.

PROBLEMS

1. An average operating data for conventional activated sludge treatment plant is as follows:

(i)	MLSS	= 1500 to 3000 mg/l
(ii)	MLVSS/MLSS	= 0.8
(iii)	F/M	= 0.4 to 0.2
(iv)	HRT (hours)	= 4 to 8
(v)	Volumetric loading (kg BOD_5/m^3)	= 0.3 to 0.7
(vi)	SRT (days)	= 5 to 15
(vii)	Return Sludge Ratio	r = 0.25 to 0.5 = 25% to 50%
(viii)	BOD removal efficiency	= 85 to 95%
(ix)	kg oxygen required per kg BOD_5 removal	= 0.8 to 1.1
(x)	Air required per kg BOD_5 (m^3)	= 40 to 100.

Determine:

(i) Aeration period (hours).

(ii) F/M kg BOD per d/kg MLSS.

(iii) Percentage efficiency of BOD removal.

(iv) Sludge age (days).

Solution:

(i) Aeration period (0) in hours:

Waste Water Flow	–	**35000 m^3/d-(Q).**
Volume of Aeration Tank	–	**10900 m^3-(V).**
Influent BOD	–	**250 mg/l-(S_O/ Y_O).**
Effluent BOD	–	**20 mg/l-(S_E/ Y_E).**
Mixed Liquor Suspended Solids, (MLSS)	–	**2500 mg/l-(X_t).**
Effluent Suspended Solids,	–	**30 mg/l-(X_E).**
Waste sludge suspended solids,	–	**9700 mg/l-(X_R).**
Quantity of waste sludge,	–	**220 m^3/d-(Q_W).**

(ii) F/M ratio:

$$t=\frac{V}{Q}\times 24=\frac{10900}{35000}\times 24=7.5 \text{ hours.}$$

(iii) Percentage efficiency of BOD removal:

$$\eta = \frac{\text{Incoming BOD} - \text{Outgoing BOD}}{\text{Incoming BOD}} = \frac{250-20}{250} \times 100\%$$

$$= 92\%.$$

(iv) Sludge age in days (θc):

$$\theta_C = \frac{V \cdot X_t}{Q_w \cdot X_R + (Q - Q_w) \cdot X_E}$$

$$= \frac{10900 \times 2500}{220 \times 9700 + (35000 - 220) \times 30} \quad \text{(convert mg/}l\text{ to kg/m}^3\text{)}$$

$\theta_C = 8.58$ days.

2.

Waste water flow	$Q = 50{,}000\ m^3/d.$
Volume of aeration tank	$V = 15500\ m^3.$
Influent BOD	$S_O/Y_O = 200\ mg/l$
Effluent BOD	$S_E/Y_E = 25\ mg/l$
Mixed Liquor Suspended Solids (MLSS)	$X_t = 3000\ mg/l$
Effluent Suspended Solids	$X_E = 40\ mg/l$
Suspended Solids in Waste Sludge	$X_R = 12000\ mg/l$
Quantity of Waste Sludge	$Q_W = 250\ m^3/d.$

For the above data, determine (i) Aeration Period, (ii) F/M ratio, (iii) BOD removal efficiency, (iv) Sludge Age.,

Solution:

(i) Aeration Period

$$\theta = \frac{V}{Q} \times 24$$

$$= \frac{15500}{50000} \times 24 = 7.44 \text{ hours.}$$

(ii) F/M ratio

$$F/M = \frac{Q \cdot Y_o}{V \cdot X_t} = \frac{50000 \times 200}{15500 \times 3000} = 0.215 \text{ kg BOD per day/kg of } \mathbf{MLSS}.$$

Note:

$$\boxed{\begin{aligned} &MLVSS = 0.8 \times 3000 = 2400\ mg/L \\ &\because \frac{MLVSS}{MLSS} = 0.8. \end{aligned}}$$

$$\text{Hence } F/M = \frac{50{,}000 \times 200}{15{,}500 \times 2400} = 0.269 \text{ kg BOD per day/kg of } \mathbf{MLVSS}.$$

(iii) Percentage efficiency of BOD removal

$$\eta = \frac{200-25}{200} \times 100 = 87.5\%$$

(iv) Sludge age

$$\theta_C = \frac{V \cdot X_t}{Q_w \cdot X_R + (Q - Q_w) \cdot X_E}$$

$$= \frac{15{,}500 \times 3000}{(250 \times 12000) + (50{,}000 - 250) \times 40}$$

$$\theta_C = 9.32 \text{ days.}$$

TRICKLING FILTERS

• It is an Aerobic and Attached Growth process (the microorganisms remain attached to the filter media).

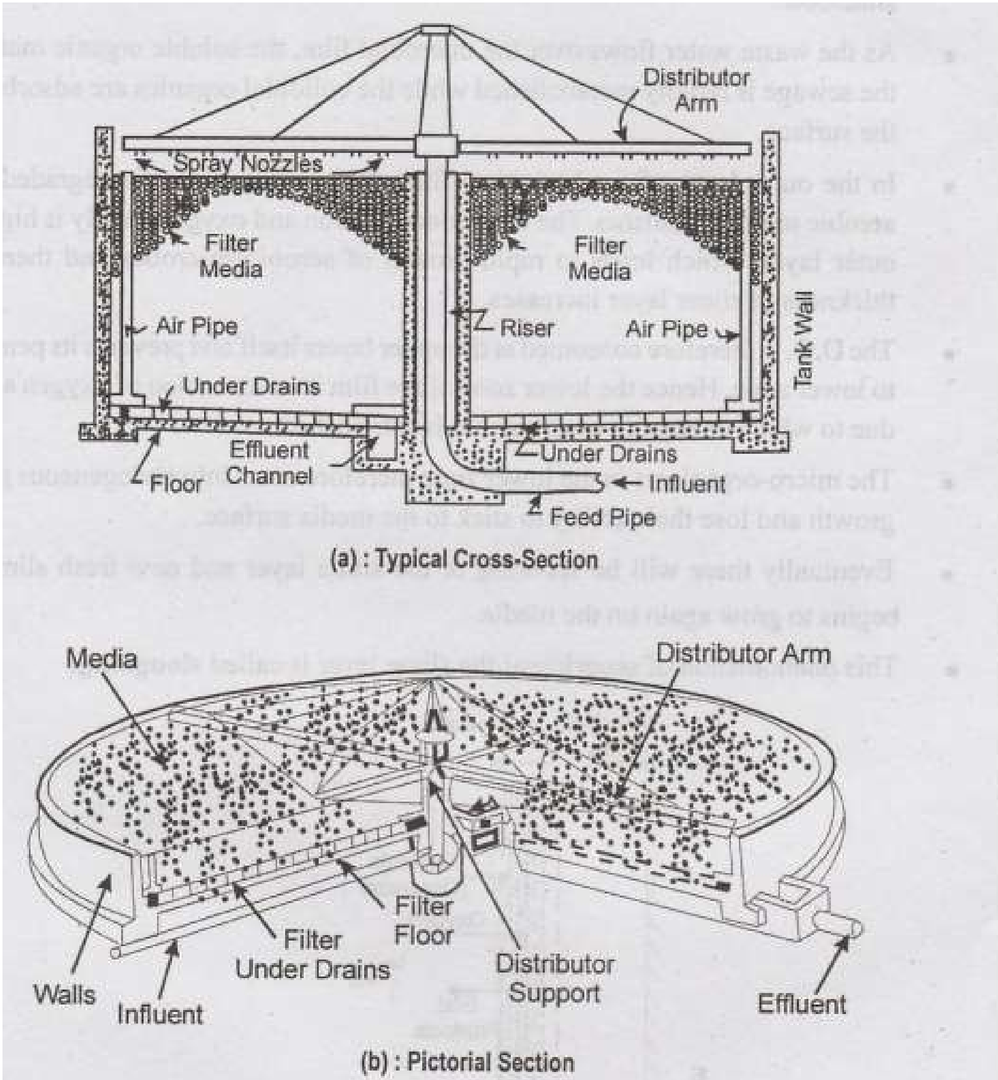
• Trickling filters are also known as percolating filters (or) sprinkling filters.

• Sewage is allowed to sprinkle (or) trickle over a bed of coarse, rough, hard filter media and it is then collected in the under-drainage system.

• Spray nozzles (or) rotary distributors provided on top are used for sprinkling sewage diwong on filler media.

• The biological purification is brought about mainly by aerobic bacteria, which form a bacterial film (biofilm) around particles of filter media.

• The color of this film is blackish, greenish and yellowish and apart from bacteria it or may consist of fungi, algae, protozoa, etc.



(a) : Typical Cross-Section

(b) : Pictorial Section

Fig. 5.17. Trickling Filters

- Sufficient O2 (oxygen) is supplied inside filter for the existence of this bio-film.

- Organics are removed by bisorption.

- The trickling filter is always preceded by primary sedimentation tank along with the skimming devices to remove the scum. This will prevent the clogging of the filter by settleable solids.

- The effluent from the filter is then taken to secondary sedimentation tank for settling out organic solids oxidised while passing through the filter.

- The microbial film (or biofilm) (or) the slime film formed on the filter medium is aerobic to a depth of only 0.1 to 0.2 mm, and the remaining part of the film is anaerobic.

• As the waste water flows over the microbial film, the soluble organic material in the sewage is rapidly metabolished while the colloidal organics are adsorbed onto the surface.

• In the outer layer of the biological film, the organic matter is degraded by the aerobic micro organisms. The food concentration and oxygen supply is high at the outer layer, which leads to rapid growth of aerobic microbes and thereby the thickness of slime layer increases.

• The D.O. is therefore consumed at the upper layers itself and prevents its penetration to lower zone. Hence the lower zone of the film is in starvation of oxygen and food due to which anaerobic environment is established.

• The micro-organisms in the lower zone therefore enter into endogeneous phase of growth and lose their ability to stick to the media surface.

• Eventually there will be scouring of the slime layer and new fresh slime layer begins to grow again on the media.

• This phenomenon of scouring of the slime layer is called sloughing.

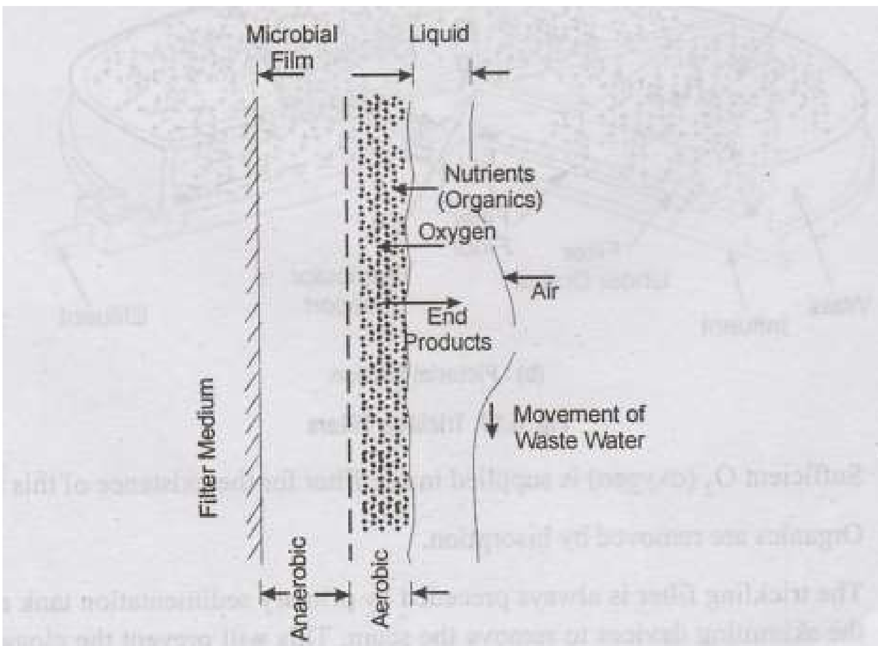


Fig. 5.18 : Attached Growth Process in a Trickling Filter

Classification of Trickling Filters:

(i) Low Rate Trickling Filters (or) Standard Rate Trickling Filter (SRTF)

(ii) High Rate Trickling Filters (HRTF).

Construction of Conventional Trickling Filters:

• A trickling filter consists of:

(i) A water tight holding tank made of masonry or concrete walls.

(ii) Distribution system

(iii) Filter media and

(iv) Under-drainage system.

• Tank is either square, rectangular or circular in shape.

• Influent to the trickling filter is from the primary sedimentation tank.

Filter Media:

• The filter media used should have high surface area, high void space, resistance to abrasion and insoluble.

• Particles of filter media should be round (or) cubical in shape. The filtering media should be free from flat (or) elongated pieces and should not contain dirt.

• The most commonly used filter media is broken stone, slag (or) gravel of size 25 to 75 mm.

• The media should be packed atleast 30 cm height above the under drainage.

• The filter depth varies from 1.8 m to 3.0 m.

Under-Drainage System:

• The purpose of under-drainage system:

(a) To carry the liquid effluent and sloughed biological solids.

(b) To distribute air throughout the bed.

• They are formed of precast vitrified clay (or) concrete blocks with perforated cover.

• The slope of the under drain should be same as that of floor sloping towards a common collection point.

• At design flow, the velocity of drains may be 0.6 to 0.9 m/s.

Main Collecting Channel:

Water Supply and Waste Water Engineering

• The main collecting channel is provided to carry away the flow from the under drains and to admit air to the filter. pontot dgil (0

• The main collecting channel shall have semi-circular (or) other rounded inverts.

• The velocity shall not be less than 0.6 m/s.

Filter Floor:

• The filter floor should be strong enough to support the under-drainage system.

• An R.C.C. slab of 10 to 15 cm thick is provided.

Filter Walls:

• Filter walls may either be fully plastered stone (or) brick masonary (or) R.C.C.

Ventilation:

• Natural ventilation is ensured by providing under drains or forced ventilation is of somalais done with air flow of 1 m3/min/m2 of filter area.

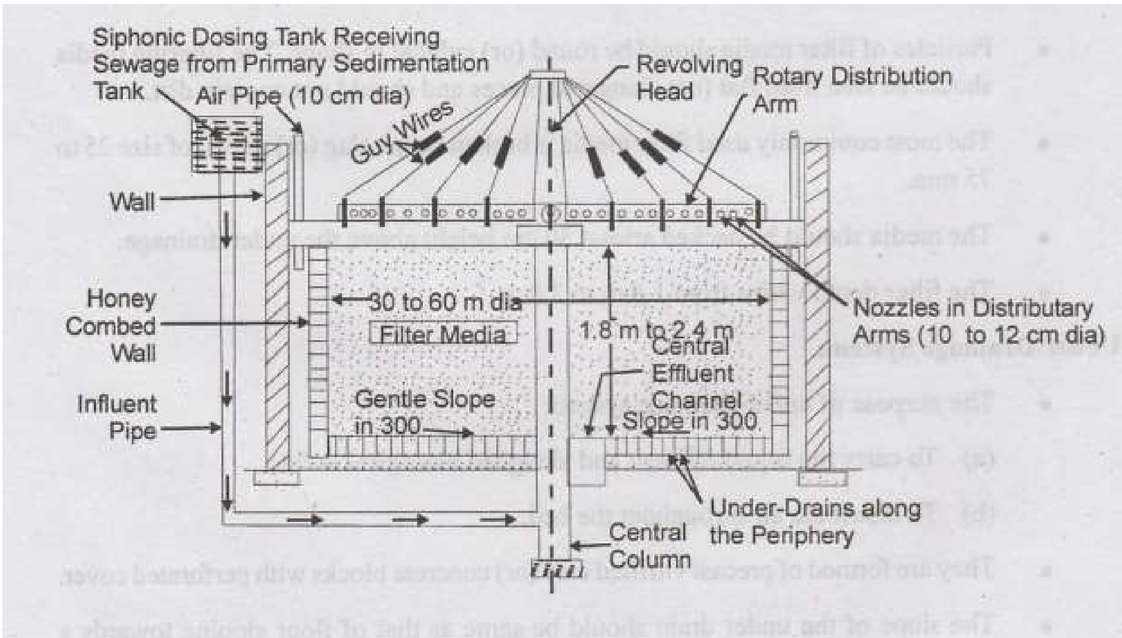


Fig. 5.19 : Conventional Circular Trickling Filter with rotary distributors

Types of Trickling Filters

• Conventional Trickling Filter/Ordinary/Standard/Low rate - No recirculation of sewage.

• High Rate Trickling Filter - Recirculation of Sewage (as in ASP), greater loading, less space requirement and less filter media.

Table 5.3 : Comparison of Trickling Filters

Characteristics	Conventional (Standard Rate) Trickling Filters	High Rate Trickling Filters
i) Depth of filter media	1.6 m to 2.4 m	1.2 m to 1.8 m
ii) Size of filter media	25 mm to 75 mm	25 mm to 60 mm
iii) Land required	More as filter loading is less.	Less land area is required. More loading of filters.
iv) Cost of operation	More	Less
v) Method of operation	Continuous and less flexible.	Continuous and more flexible (skilled attention is required).
vi) Sloughing	Intermittent	Continuous
vii) Type of effluent produced	Highly stabilised, nitrified BOD $\leq$ 20 ppm.	Less stable and inferior quality, BOD $\geq$ 30 ppm.
viii) Dosing interval	3 to 10 min	> 15 seconds.
ix) Filter loading	1-4 $m^3/d/m^2$	10 to 30 $m^3/d/m^2$
• Hydraulic loading	20 to 44 M.L/ha/day	110 to 330 ML/ha/day.
• Organic loading	900 to 2200 kg BOD_5/ ha/m of filter media/day (or) 80 to 320 $g/d/m^3$.	6000 to 18000 kg BOD_5 / ha/m of filter media/day (or) 500 to 1000 $g/d/m^3$.
x) Recirculation	Not done	Provided (increases hydraulic loading).
xi) Quality of secondary sludge	Black, highly oxidised	Brown, not fully oxidised.

High Rate Filtration:

(1) As the sewage flow is increased, the thickness of gelatinous biofilm is reduced, and the organic materials deposited on the contact surface is continuously washed away with effluent.

(2) Thinner bioflim is more efficient and supplies more continuous nutrients to the aerobic bacteria.

(3) The precipitation and biological coagulation of the dissolved and colloidal matter is more (or) less same as in normal rate filters.

(4) Lesser oxidation of organic matter because of reduction in the contact period.

(5) Since large quantity of putrescible organic material reaches the secondary settling tank, the load on the secondary settling tank is increased.

(6) The sludge produced is not easily digestible.

(7) Cost of construction and land decreases with the increase in rate of filtration.

To achieve high rate filtration, the following modifications are made in conventional trickling filter:

(1) Better quality filtering media is used, larger size stone media (or) plastic synthetic media is used.

(2) The depth of filter media is reducd to 1.5 m - 2.0 m to obtain better aeration.

(3) The size of under-drains is increased and their slope is also inade steeper so that the effluent can be collected and quickly conveyed to secondary settling tank.

(4) The speed of rotating arm is increased.

(5) The size of secondary settling tank is also increased to cope with the quantity of flow and bio-flocculent solids coming out.

Classification of High Rate Trickling Filter

(i) Single-Stage High Rate Trickling Filter

(ii) Two-Stage High Rate Trickling Filter

Classification of High Rate Trickling Filter

(i) Single-Stage High Rate Trickling Filter

(ii) Two-Stage High Rate Trickling Filter

(i) Single Stage HRTF

• Single stage unit consists of one primary settling tank, one trickling filter, one bs secondary settling tank and facilities for recirculation.

• Settling before recirculation is carried out either in primary (or) secondary clarifier.

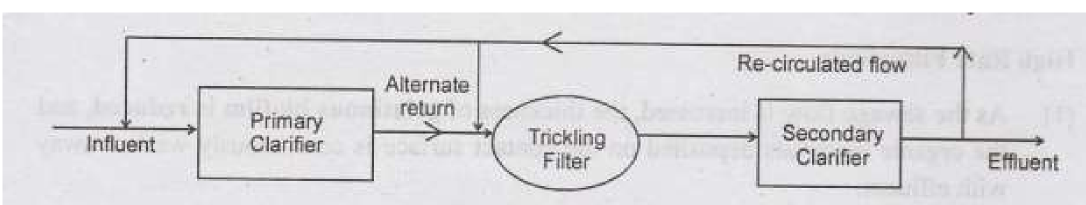


Fig. 5.20 : Single Stage Trickling Filter

(ii) Two Stage HRTF:

• Two stage filters consists of two trickling filters in series with a primary settling tank, an intermediate settling tank (optional) and a final settling tank.

• Recirculation facilities are provided for each stage.

• The effluent from first stage is applied to the second stage either after settlement (or) without settlement.

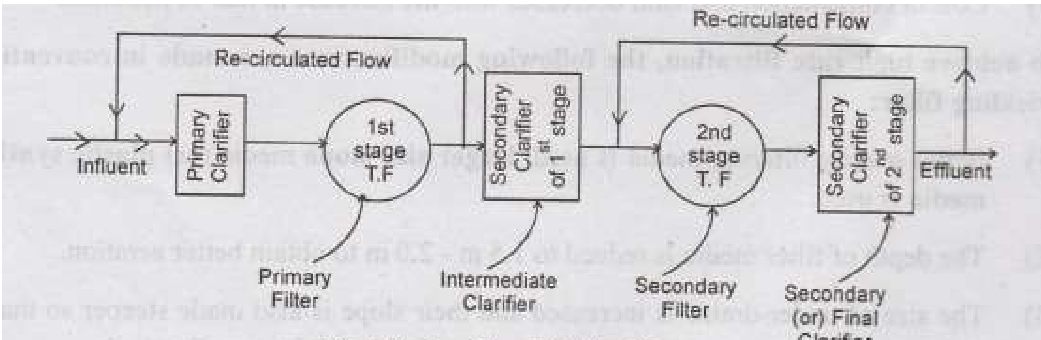


Fig. 5.21 :Two-Stage Trickling Filter

• An intermediate clarifier is used for settling the first stage effluent before it is applied to the second stage filter.

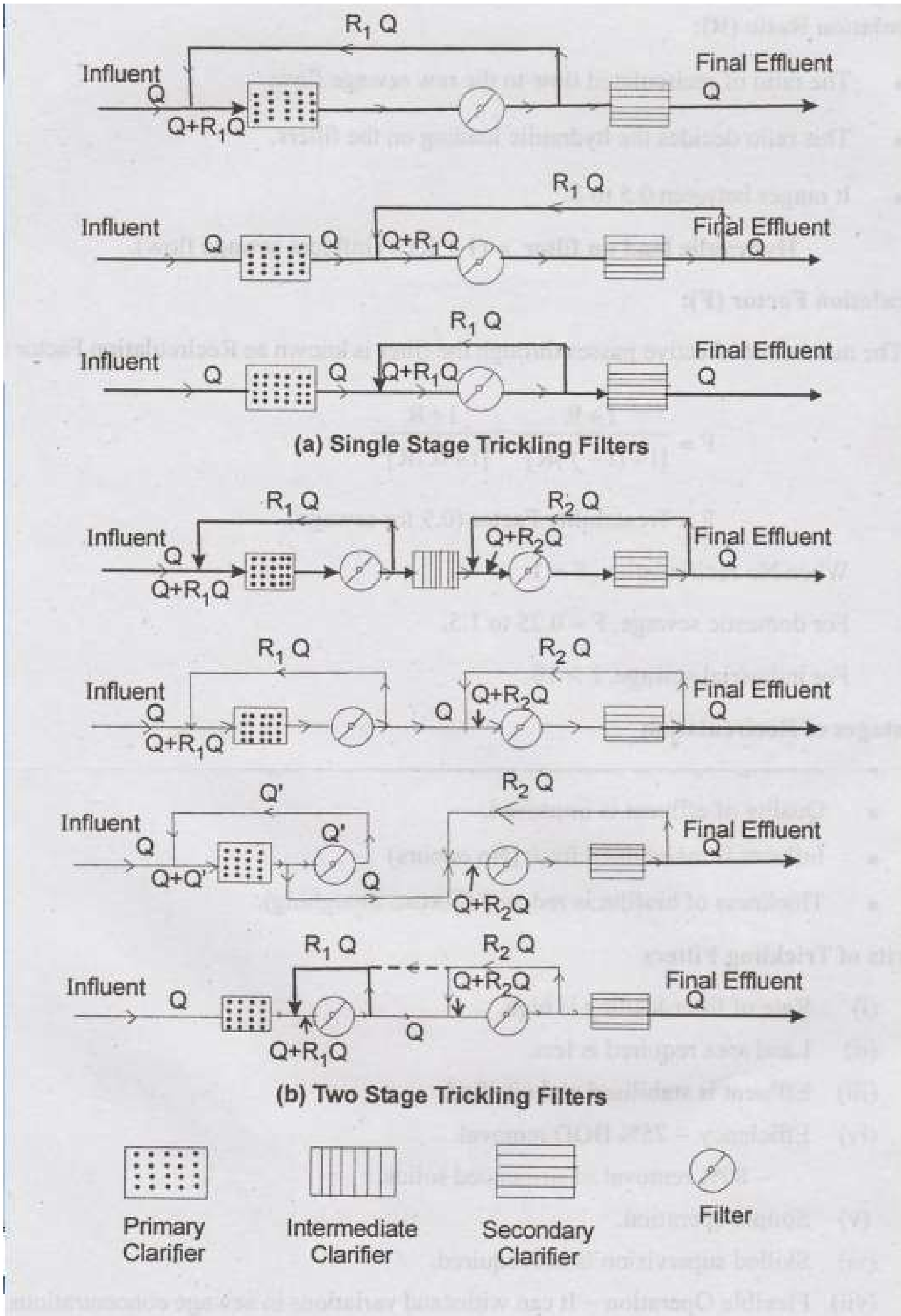


Fig. 5.22 : Flow Diagrams for High Rate Trickling Filters

Recirculation Ratio (R):

- The ratio of recirculated flow to the raw sewage flow.
- This ratio decides the hydraulic loading on the filters.

• It ranges between 0.5 to 3.

Hydraulic load on filter = (1 + R) × (influent sewage flow).

Recirculation Factor (F):

The number of effective passes through the filter is known as Recirculation Factor (F).

$$F = \frac{1+R}{[1+(1-f)R]^2} = \frac{1+R}{[1+0.1R]^2}$$

F = Treatability Factor (0.9 for sewage)

When No recirculation, F = 1

For domestic sewage, F = 0.25 to 1.5.

For industrial sewage, F > 10.

Advantages of Recirculation

• Seeding improves microbes concentration in sewage.

• Quality of effluent is improved.

• Influent is maintained fresh (No odours)

• Thickness of biofilm is reduced (Forced Sloughing).

Merits of Trickling Filters

(i) Rate of filter loading is high.

(ii) Land area required is less.

(iii) Effluent is stabilised and nitrified.

(iv) Efficiency - 75% BOD removal.

- 80% removal of suspended solids.

(v) Simple operation.

(vi) Skilled supervision is not required.

(vii) Flexible Operation - It can withstand variations in Sewage concentrations.

(viii) They are self-cleaning.

(ix) Mechanical wear and tear is small as they contain less mechanical equipment.

(x) Operates more efficiently in warm weather. Very useful in hot countries like India.

Demerits of Trickling Filters

(i) Head loss is high

(ii) Automatic dosing of filters is necessary

(iii) Construction cost is high

(iv) Cannot treat raw sewage. Primary sedimentation (pretreatment) of sewage is a must.

(v) Pose Operational troubles such as fly nuisane, odous nuisance and ponding problems.

Operational Problems in Trickling Filter

(a) Fly Nuisance: Psychoda fly grows on the filter media and may cause nuisance to the nearby habitation.

Control: (i) Flooding the filter with sewage for 24 hours or more will destroy the larvae.

(ii) Using insecticides like D.D.T, Chlordane and Benzene Hexachloride.

(b) Odour Nuisance: Odours do not prevail in trickling filters using rotary distributors. However when fixed nozzles are used, H2S and other odourous gases are released from the sprays into atmosphere.

Remedy: (i) Chlorinate the sewage to prevent H2S formation.

(ii) Keep sewage fresh by re-circulation.

(c) Ponding Trouble: Due to heavy growth of fungi and algae, the voids of the filter media gets clogged and result in ponding of sewage over filter bed.

Remedy: (i) Chlorinating sewage to kill the algae.

(ii) Adding copper sulphate in sewage to control algae.

PROBLEMS

3.

The sewage is flowing at 4.5 ML per day from a primary clarifier to a standard rate T.F. The 5-day BOD of influent is 160 mg/L. The value of adopted organic loading is 160 g/m3/d. Surface loading is 2000 l/m2/d. Determine volume of filter and depth. Calculate efficiency of filter unit.

Solution:

Total 5-day BOD in sewage

$$= 160 \text{ mg}/l \times 4.5 \times 10^6 \text{ l/d}$$

$$= 720000 \text{ g/d.}$$

$$\text{Volume of filter media} = \frac{\text{Total BOD}}{\text{Organic loading rate}} = \frac{7{,}20{,}000\, g/d}{160\, g/m^3/d}$$

$$= 4500 \text{ m}^3.$$

Surface area required for filter

$$= \frac{\text{Total flow}}{\text{Hydraulic loading rate}}$$

$$= \frac{4.5 \times 10^6\, l/d}{2000\, l/m^2/d}$$

$$= 2250 \text{ m}^2.$$

$$\text{Depth} = \frac{\text{Volume}}{\text{Surface area}} = \frac{4500\, m^3}{2250\, m^2} = 2 \text{ m.}$$

u = Organic loading in kg/ha-m/d

Organic loading = 160 g/m³/d

$$= 160 \times \frac{10^4}{10^3} \text{ kg/ha-m/d}$$

$$= 1600 \text{ kg/ha-m/d}$$

$$\eta = \frac{100}{1 + 0.0044\sqrt{u}} = \frac{100}{1 + 0.0044\sqrt{1600}}$$

$$= \frac{100}{1.176} = 85.3\%$$

$$\boxed{\eta = 85.3\%.}$$

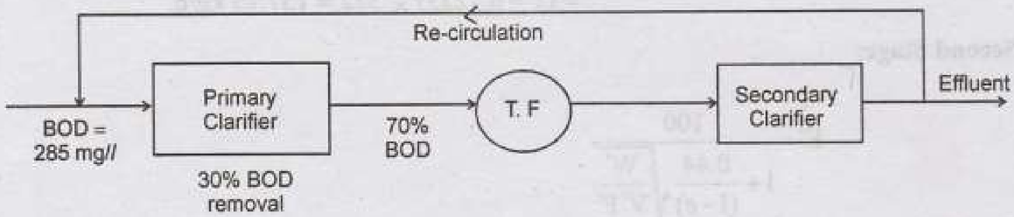
4. Design a HRTF for treating domestic sewage with a BOD of 285 mg/l and average flow of 40 MLD. The effluent BOD desired is 10 mg/l. Use NRC equation.

Solution:

Flow = 40 MLD = 40 $\times$ 10^3 m^3/d.

30% BOD removal from primary clarifier

$$\text{BOD} = \frac{0.7 \times 40 \times 10^6\, m^3/d \times 285}{10^6}\ \text{mg}/l = 7980\ \text{kg/day}.$$



HRTF – Organic loading = 500 to 1000 g/d/m^3

$= 0.8\ \text{kg/d/m}^3$.

$$\text{Volume of trickling filter} = \frac{\text{Total BOD in sewage}}{\text{Organic loading rate}}$$

$$= \frac{7980\,kg/d}{0.8\,kg/d/m^3} = 9975\ \text{m}^3.$$

Adopt two units

$$\text{Volume of each unit} = \frac{9975 m^3}{2} = 4987.5\ \text{m}^3.$$

Assume depth of media = 2 m.

$$\text{Surface Area} = \frac{\text{Volume}}{\text{Depth}} = \frac{4988}{2}\ \frac{m^3}{m} = 2494\ \text{m}^2$$

$$\frac{\pi}{4}\, d^2 = 2494\ \text{m}^2$$

$$\boxed{d = 56\ \text{m.}}$$

Assume recirculation ratio of 2.

$$\text{Recirculation factor} = \frac{1+R}{(1+0.1R)^2}$$

$$= \frac{1+2}{(1+0.1\times 2)^2}$$

$$F = 2.083.$$

Load on stage 1 T.F, $W_1 = 7980$ kg/d.

$$\text{Efficiency of } 1^{st} \text{ stage, } E_1 = \frac{100}{\left(1+0.44\sqrt{\frac{W}{VF}}\right)}$$

$$= \frac{100}{1+0.44\sqrt{\frac{7980}{4988\times 2.083}}}$$

$$= 72.17\%$$

Influent BOD = 0.7 × 285 = 199.5 mg/*l*

Effluent BOD = 10 mg/l.

$$\text{Total BOD removal efficiency} = \frac{199.5-10}{199.5}\times 100 = 94.98\%.$$

Efficiency of 2[nd] stage

$$E_2 = E - E_1$$

$$= 94.98 - 72.17$$

$$= 22.81\%$$

BOD load on second stage T.F.

$$W_2 = (1 - 0.7217) \times W_1$$

$$= (1 - 0.7217) \times 7980$$

$$\boxed{W_2 = 2220.83 \text{ kg/d.}}$$

$R = 2,\ F = 2.083.$

Using NRC equation,

Efficiency of 2nd stage T.F.

$$E_2 = \frac{100}{1 + \frac{0.44}{(1-E_1)}\sqrt{\frac{W_2}{V_2 \cdot F}}}$$

$$22.81 = \frac{100}{1 + \frac{0.44}{(1-0.7217)}\sqrt{\frac{2220.83}{V_2 \times 2.083}}}$$

$$1 + 1.58\sqrt{\frac{1066.16}{V_2}} = 4.384$$

$$\sqrt{\frac{1066.16}{V_2}} = 2.142$$

$$\boxed{V_2 = 232.37 \text{ m}^3.}$$

Assume depth = 2 m.

$$\text{Area} = \frac{\text{Volume}}{\text{Depth}} = \frac{232.37}{2} = 116.18 \text{ m}^2$$

$$\frac{\pi}{4} d^2 = 116.18$$

$$\boxed{d = 12.16 \text{ m} \simeq 12.50 \text{ m}}$$

Results:

Ist stage T.F = 56 m ϕ

IInd stage T.F = 12.50 m. ϕ

SEQUENTIAL BATCH REACTOR (SBR)

• The first is to make certain that all mechanical, electrical and control equipment is operating properly.

• The purpose of Fill-React operation is to add substrate (raw sewage) to the reactor. The addition of substrate or filling is controlled by a timer to a set time period. The filling operation is also controlled by level transmitter to limit filling volume upto maximum level. Usually, SBR tanks are designed to take flow as it comes into STP with all variations from peak flow to minimum flow without necessiating any equalization tank.

• The settling process is controlled by time and is usually fixed between 30 minutes to an hour so that the sludge blanket remains below the withdrawal mechanism during the next phase.

• The purpose of Decantation is to remove the clarified, treated water from the reactor.

• When starting the plant initially, the diffuser should be operated first and run continuously, otherwise the desired parameters will not be achieved. egbuia odoriw ang nilure,

• The precaution needed is to make sure that power supply is available continuously. If power supply fails, immediately bring the genseton-line.

• COD to BOD ratio indicates the biodegradabitity of the sewage. Normally, sewage will have COD to BOD ratio between 1.5 to 2. If the ratio is more than 2, entry of industrial effluents into sewer network is a possibility.

• The daily tests shall be COD, TSS, pH, Dissolve oxygen, Ammonia and dissolved phosphate. BOD can be a weekly test.

UASB (SUSPENDED GROWTH SYSTEM)

Upflow Anaerobic Sludge Blanket.

(High Rate Anaerobic System).

• The UASB reactor maintains a high concentration of biomass through the formation of highly settleable microbial sludge aggregates.

• Waste water flows upwards through a layer of very active sludge (Sludge Bed) to cause anaerobic digestion of organics of the waste water.

• At the top of reactor, three phase separation between gas-solid-liquid takes place.

• This process is suitable for both soluble waste water as well as waste waters containing particulate matter.

• The waste water enters the tank from the bottom and flow upwards through the sludge bed, which is formed during the process itself.

• The sludge bed consists of anaerobic and facultative micro-organisms capable brb of flourishing in a oxygen deficient environment.

• The sludge bed (blanket) traps the suspended organics from the upflowing sewage which are degraded by anaerobic and facultative bacteria, which produce methane (CH_4) and carbondioxide (CO_2) (Biogas).

• The bidog notebi of boyaging sol al beril biogas produced helps in gentle mixing and stirring of biomass thereby increasing the efficiency of decomposition and reducing the BOD and suspended solids concentration of the waste water.

• The gas produced is sufficient to keep the sludge fully mixed.

• The biogas consists of 65 to 70% CH_4 and 30 to 35% CO_2.

• The methane (or) biogas is collected at at the top of the t

• The water sludge mixture is made to enter a settling tank, where the sludge settles down and flows back into the bottom of the reactor.

• The sludge has good settling properties.

• There is no packing material. The microbes attach to each other or to small particles, agglomerate, granulates to form sludge bed or blanket.

• Retention time is about 6-8 hours with continuous bacterial presence.

• The treated effluent is collected in gutters and discharged out of the reactor.

• The methane generated can be used for generating electricity to run the plant.

• The sludge is dewatered in drying beds and used as soil enricher.

Advantages:

(i) Space required is less compared to ASP/Oxidation pond/Aerated lagoons.

(ii) bn Capital cost is less.

(iii) System requires lesser/simpler electromagnetic parts.

(iv) Low operation and maintenance cost.

(v) Electricity consumption is low and can withstand power failures.

(vi) Quicker sludge digestion.

(vii) Low sludge production. Sludge has quick dewatering properties.

(viii) Biogas produced as by-product is used for electricity generation.

(ix) Used for treatment of high strength waste waters like those from municipalities and industries like food processing, distilleries, dairies, etc.

Disadvantages:

(i) System lowers only two parameters of waste water.

(a) BOD

(b) Suspended solids.

It does not remove heavy metals and toxic pollutants.

(ii) Require larger quantity of organic matter (20 to 30 times) for growth of anaerobic bacteria.

(iii) Acids produced by breakdown of organic matter in UASB - may cause corrosion of reactor.

(iv) Efficiency of BOD/SS removal is low.

(v) Pretreatment (Screening/Grit Removal) is necessary.

WASTE STABILIZATION PONDS OR BASINS (OXIDATION PONDS/ LAGOONS)

• Stabilisation ponds are open, flow through earthern basins, designed and constructed to treat domestic sewage and biodegradable industrial waste waters.

• WSBS have long detention periods, extending to several days.

• Low cost system and is used in rural areas.

• These ponds are completely mixed biological reactors without solids retur

Stabilisation ponds may be classified according to nature of biological activity: 1. Aerobic, 2. Anaerobic, 3. Facultative (aerobic - anaerobic).

Construction:

• These are earthern pits made of impervious soil (clay).

• Lining is provided to prevent seepage of ground water.

• The depth varies from 1 m to 1.8 m.

• The walls of the pond are sloped and the topwidth varies from 2.5 to 3 m.

• Minimum free board of 0.6 m. is provided.

• Influent enters at the centre of the pond and the effluent overflows in a corner.

• The detention time is usually 2-6 weeks.

• In the stabilisation ponds, microbial plants like algae, protozoans, bacteria and rotifers grow and metabolize the organic wastes in sewage.

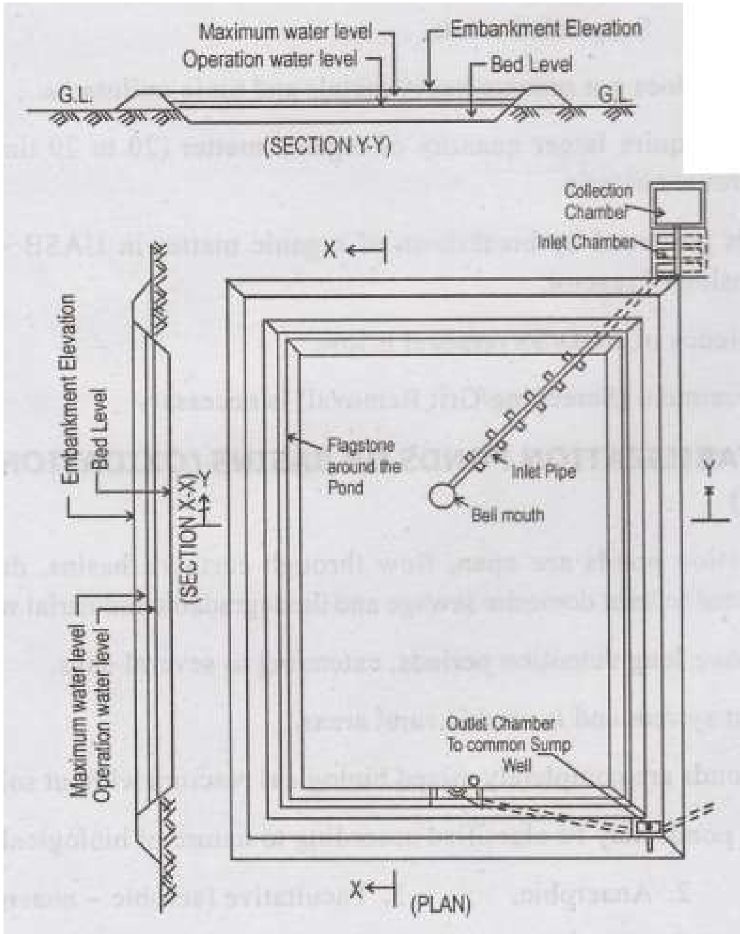


Fig. 5.24 : Oxidation Pond

Advantages of Stabilisation Ponds

(i) Low initial cost

(ii) Low operating cost.

(iii) Regulation of effluent discharge is possible.

Disadvantages

(i) Requires extensive land required laertnyeol esgl Used in rural areas.

(ii) Odour problems.

(iii) Effluent quality standard of 30 mg/l for suspended solids is not met.

Oxygen transfer depends on:

(i) Lagoon surface area to volume.

Larger the ratio, better will be the O2 diffusion into the lagoon. ailuast doidwa

(ii) Temperature of lagoon.

Greater solubility of O, in water and hence greater diffusion rate at lower temperature.

(iii) Turbulence.

Generally provided by the wave action.

(iv) Bacterial oxygen uptake rate.

The faster the microbes consume D.O, the greater will be the rate at which oxygen is replenished.

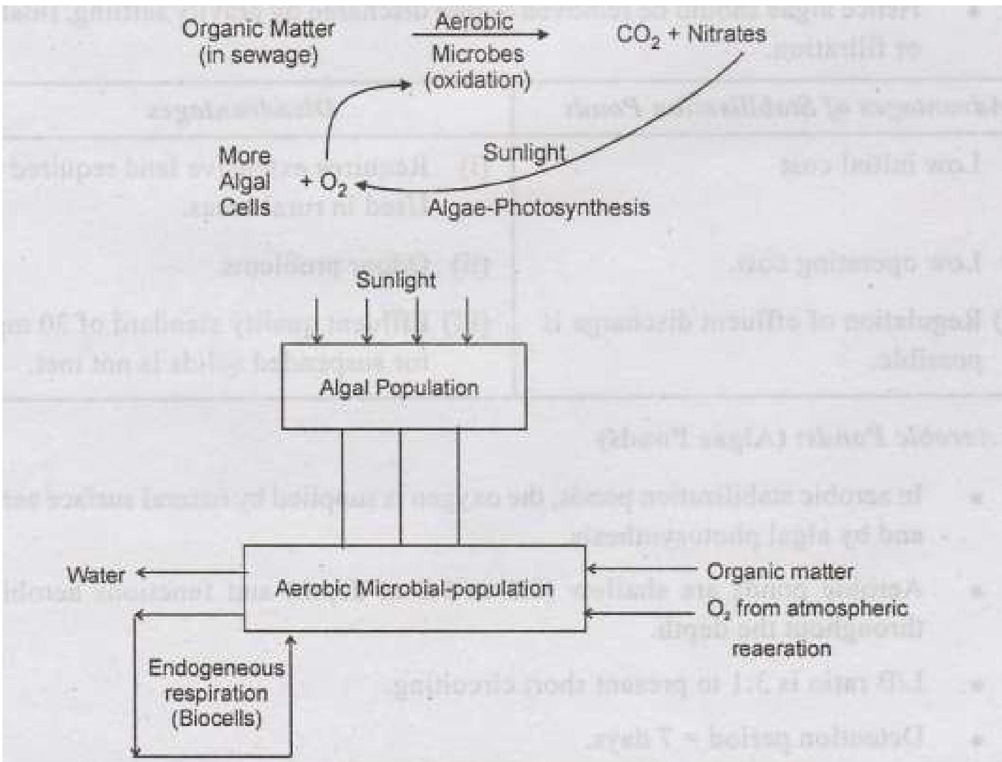


Fig. 5.25 : Algal-Bacterial Symbiosis in an Aerobic Lagoon

Advantages of Oxidation Ponds

- Cheap and low cost process.
- Suitable for small towns and cities.
- Suitable for hot dry country (India).
- Low maintenance.
- No skilled supervision required.
- Flexible for fluctuations in flow and organic loading.

Disadvantages of Oxidation Ponds

- Mosquito Breeding.
- Algal growth.
- Bad Odours.

PROBLEMS

Design an oxidation pond for treating sewage from a hot climatic residential colony with 5000 persons contributing sewage @ 120 lpcd. The five day BOD of sewage is 300 mg/l.

Solution:

(i) Quantity of sewage treated per day = Population x Sewage contribution. = 5000 x 120 lpcd = 6,00,000 litres. = 600 m3/d or 0.6 MLD.

(ii) BOD content per day.

Total BOD = Discharge x BOD concentration

(iii) Assume organic loading in pond (Hot climate) = 300 kg/ha/day.

Surface area required = Total BOD of sewage/ Organic loading rate

= 180 kg/d/ 300kg/ha/d = 6000 m2.

(iv) Assume L/B = 2.

L x B = 6000 m2

2B x B = 6000

B = 55 m

L= 2 x 55 110 m.

(v) Assume effective depth = 1.2 m.

(vi) Volume (capacity) of pond. = L x B x H

= 110 x 55 x 1.2 = 7260 m3.

(vii) Capacity = Sewage flow per day x Detention time (days).

D.T= Capacity/Flow =7260 m3 600m3/d =12.1 days = 12 days.

LotfupzoM diwong legiA anobo bad

Result:

Use oxidation pond with

Length = 110 m; Width = 55 m.

Overall depth = (1.2 + 1) = 2.2 m.

Detention period = 12 days.

OTHER TREATMENT METHODS

• It is a modified activated sludge process (ASP). It eliminates primary sedimentation and sludge digestion.

• As the aeration time is longer, it is called extended aeration process.

• Oxidation-ditch plant is economical for population upto 1.5 lakh, compared

• Land requirement is less.

• Oxidation ditch plant involves the construction of number of ditch channels, placed side by side having depth of 1-1.5 m, width of 1-5 m based on the rotors from 150 m to 1000

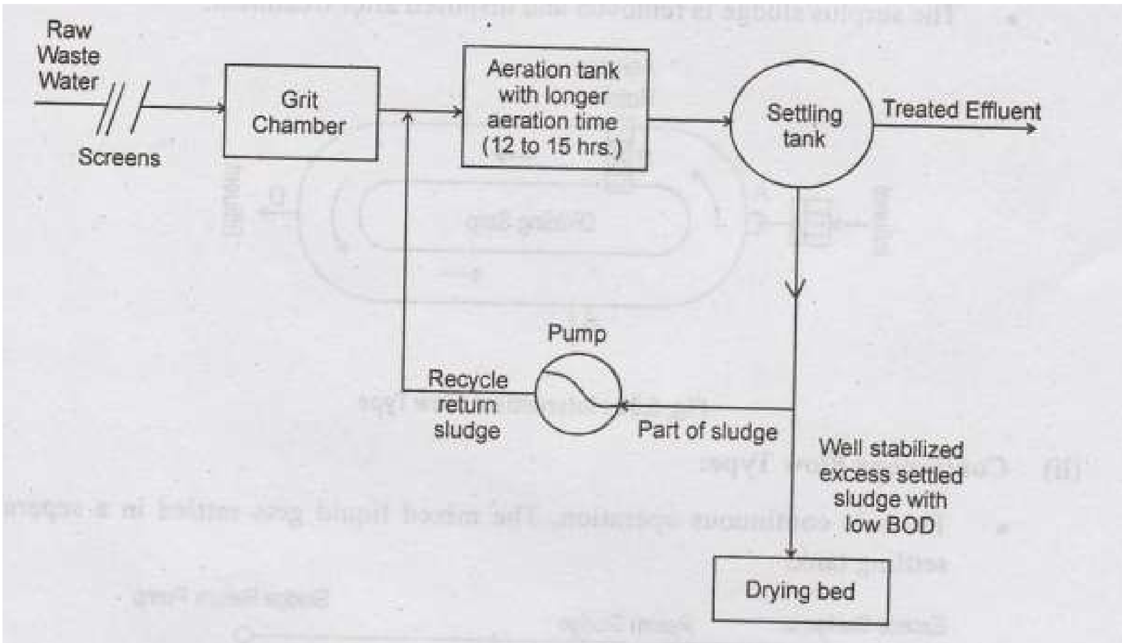


Fig. 5.29 : Extended Aeration Process

• The oxidation ditches may be constructed either in earthwork with earthern embankments (or) in brick (or) in stone masonry walls.

• Each ditch channel is equipped with a horizontal axis rotor for agitating and circulating the sewage and thereby oxygenating the sewage and keeping the sewage-solids in suspension.

• The velocity of sewage is 0.3 m/s.

• The aerated sewage is then settled in a settling tank by stopping the rotors for 2 hours.

• When rotors are stopped, the supernatant liquor is taken out.

Types of Oxidation Ditches:

(i) Intermittent Flow Type:

• There is no separate settling tank.

• When the rotor is stopped, the sludge get settled and the supernatant is 2009d withdrawn.

• The surplus sludge is removed and disposed after treatment.

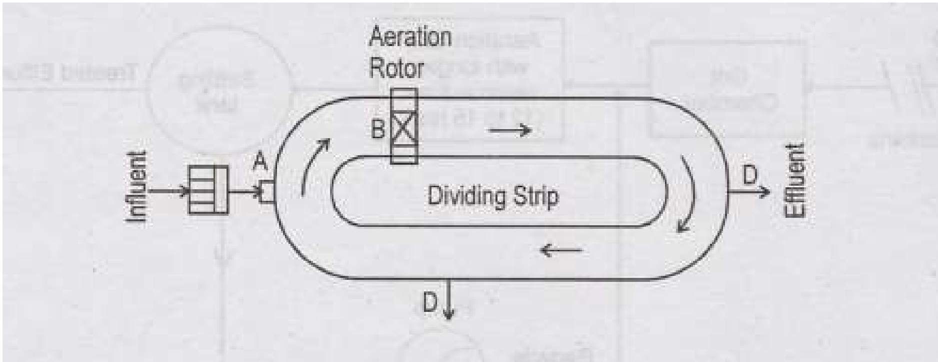


Fig. 5.30 : Intermittent Flow Type

(ii) Continuous Flow Type:

• There is continuous operation. The mixed liquid gets settled in a separate settling tank.

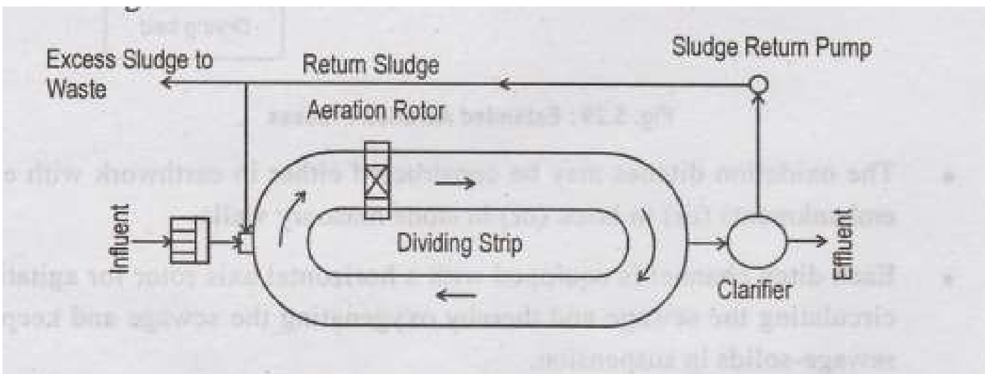


Fig. 5.31 : Continuous Flow Type

Design Considerations:

• Long aeration basin to carry MLSS conc - 3000 to 8000 mg/l.

• F/M ratio (loading factor) is low - 0

• Efficiency - 95% for suspended solids removal,

- 98% for BOD removal.

• Settled sludge which is mineralised is dried without odours.

• Detention period = 12 to 15 hours (or)

0.8 to 2.5 m3 per kg of BOD, load in sewage.

• Volume of ditch = 150 m3 per metre length of rotor.

RECLAMATION AND REUSE OF SEWAGE WASTE WATER

What is Wastewater Reuse?

The U.S. Environmental Protection Agency (EPA) defines wastewater reuse as, "using wastewater or reclaimed water from one application for another application. A common type of recycled water is water that has been reclaimed from municipal wastewater (sewage)."

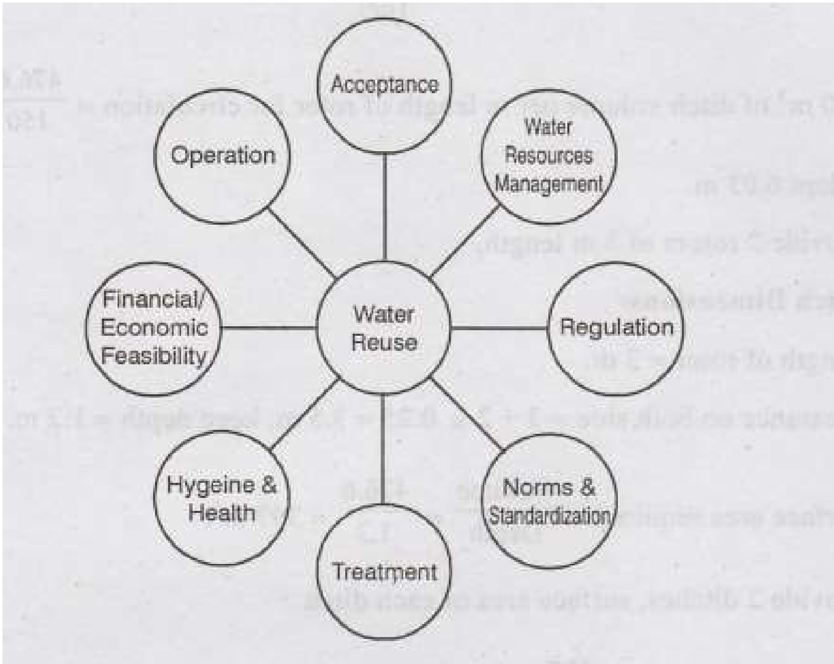


Fig. 5.32 : Continuous Flow Type

Reasons for Wastewater Reuse:

The most common reasons for establishing a wastewater reuse program is to identify new water sources for increased water demand and to find economical ways to meet increasingly more stringent discharge standards.

Types of Reuse

• Urban Reuse-the irrigation of public parks, school yards, highway medians, and residential landscapes, as well as for fire protection and toilet flushing in commercial and industrial buildings.

• Agricultural Reuse-irrigation of non-food crops, such as fodder and fibre, commercial nurseries, and pasture lands. High-quality reclaimed water is used to irrigate food crops.

• Recreational Impoundments-such as pond sand lakes.

• Environmental Reuse-creating artificial wetlands, enhancing natural wetlands, and sustaining stream flows.

• Industrial Reuse-process or makeup water and cooling tower water.

Technical Description

One of the most critical steps in any reuse program is to protect the public health, especially that of workers and consumers. To this end, it is most important to neutralize or eliminate any infectious agents or pathogenic organisms that may be present in the wastewater. For some reuse applications, such as irrigation of non- food crop plants, secondary treatment may be acceptable. For other applications, further disinfection, by such methods as chlorination or ozonation, may be necessary.

Application of Treated Wastewater

Agricultural Irrigation

• Crop irrigation

• Commercial nurseries

Landscape Irrigation

• Parks

• School yards

• Highway medians

• Golf courses

• Cemeteries

• Residential

Industrial Recycling and Reuse

• Cooling water

• Boiler feed

• Process water

• Heavy constructionib

Recreational / Environmental Uses

• Lakes & ponds

• Marsh enhancement

• Stream-flow augmentation

• Fisheries

Non-Potable Urban Uses

• Fire protection

• Air conditioning

• Toilet flushing

Potable Reuse

• Blending in water supply reservoirs

• Pipe-to-pipe water supply

• Constituents to be checked in Reclaimed Water.

Conventional (measured in mg/L; used in designing conventional WWTPs)

• TSS

• BOD; COD

• TOC

• Nitrogen (Ammonia; Nitrate; Nitrite)

• Phosphorus

• Microorganisms: Bacteria; Viruses; Protozoan cysts

Non-Conventional (to be removed or reduced by advanced treatment processes)

• Refractory organics

• VOC

• Surfactants

• Metals

• TDS

• Problems associated with Wastewater Reuse

Heavy Elements

• Public Health - nervous system disorders, mutagenesis, teratogenesis, carcinogenesis

• Bioaccumulation (food chain on crops and animals)

Surface water pollution

• Environmental Impact - acute and chronic toxicity for plant and animal life, chronic degradation effect on soil

• Nutrients (N & P)

Public Health - blue-baby syndrome (from NO3)

• Infiltration into potable water supplies

Environmental Health – Eutrophication, crop yield effects (+ive& -ive)

• Surface water pollution

• Irrigation practices

• Dissolved Solids (salinity)

Environmental Health

• Induce problems for the crops' yield selection and quantity

• Accumulation in soil

Effect on soil permeability

• Clogging drip-irrigation systems

• Emerging Pollutants

Public Health

• Acute and chronic health effects - effect on growth, reproduction problems

• Groundwater contamination

• Nitrate contamination on private drinking wells

• Antibiotics

Lower effectiveness of antibiotics if irrigation of fodder is involved

• Odour

• Public health of neighbouring communities

• Aesthetic concern - Reduced land values

Concerns with industrial processes

• Scaling

• Corrosion

• Biological growth & fouling

• Reclaimed wastewater can be safe for agricultural irrigation

• Reduce the pathogen levels

• Avoid direct contact of crops with reclaimed wastewater

• Restrict the type of crops irrigated

• Different treatment for safe irrigation of different crops:

• For tree nurseries, pastures, industrial crops

• Secondary treatment & detention in surface reservoirs

• Tertiary treatment (i.e. AS & Sand Filtration)

• For edible crops (uncooked)

• Tertiary treatment followed by soil aquifer treatment (or advanced)

Wastewater Reuse Advantages and Disadvantages

Advantages

• This technology reduces the demands of potable sources of freshwater.

• It may reduce the need for large wastewater treatment systems, if significant portions of the waste stream are reused or recycled.

• The technology may diminish the volume of wastewater discharged, resulting in a beneficial impact on the aquatic environment.

• Capital costs are low to medium for most systems and are recoverable in a very short time; this excludes systems designed for direct reuse of sewage water

• Operation and maintenance are relatively simple except in direct reuse systems where more extensive technology and quality control are required.

• Provision of nutrient-rich wastewaters can increase agricultural production in . water-poor areas.

• Pollution of rivers and groundwater may be reduced.

• Lawn maintenance and golf course irrigation is facilitated in resort areas.

• In most cases, the quality of the wastewater, as an irrigation water supply, is superior to that of well water.

Disadvantages

• If implemented on a large scale, revenues to water supply and wastewater utilities may fall as the demand for potable water for non-potable uses and the discharge of wastewaters is reduced.

• Reuse of wastewater may be seasonal in nature, resulting in the overloading of treatment and disposal facilities during the rainy season; if the wet season is of long duration and/or high intensity, the seasonal discharge of raw wastewaters may occur.

• Health problems, such as water-borne diseases and skin irritations, may occur in people coming into direct contact with reused wastewater.

• Gases, such as sulphuric acid, produced during the treatment process can result in chronic health problems.

• In some cases, reuse of wastewater is not economically feasible because of the requirement for an additional distribution system.

• Application of untreated wastewater as irrigation water or as injected recharge water may result in ground.

RECENT ADVANCES IN SEWAGE TREATMENT

• Membrane Aerated Biofilm Reactors (MABR)

• Anaerobic Membrane Bioreactor

• Aerobic Granular Sludge

• Membrane Fuel Cells

Membrane Aerated Biofilm Reactor

Membrane Aerated Biofilm Reactor (MABR) technology provides a revolutionary improvement in aerobic wastewater treatment for a number of reasons, particularly its high energy efficiency and increased treatment capacity, compared to traditional wastewater treatment systems.

Much of the energy used in aerobic treatment is tied to aeration, the introduction of air bubbles into wastewater via pumps, paddles, and other mechanisms. This enables aerobic bacteria to digest waste, but aeration can be very inefficient, so reducing this massive energy consumption is a major goal.

MABR represents one such technological breakthrough. MABR systems passively circulate oxygen through a spirally wound membrane at atmospheric pressure. MABR’s self-respiring membrane allows bacteria to consume oxygen more readily for a 90% reduction in energy used for aeration.

What’s more, the membrane surface quickly accumulates a biofilm of bacteria that establishes a Simultaneous Nitrification-Denitrification (SND) process to produce a high-quality, low-nitrogen effluent suitable for reuse in irrigation. The MABR process is also low-maintenance. All of these advantages add to an overall reduction in energy use.

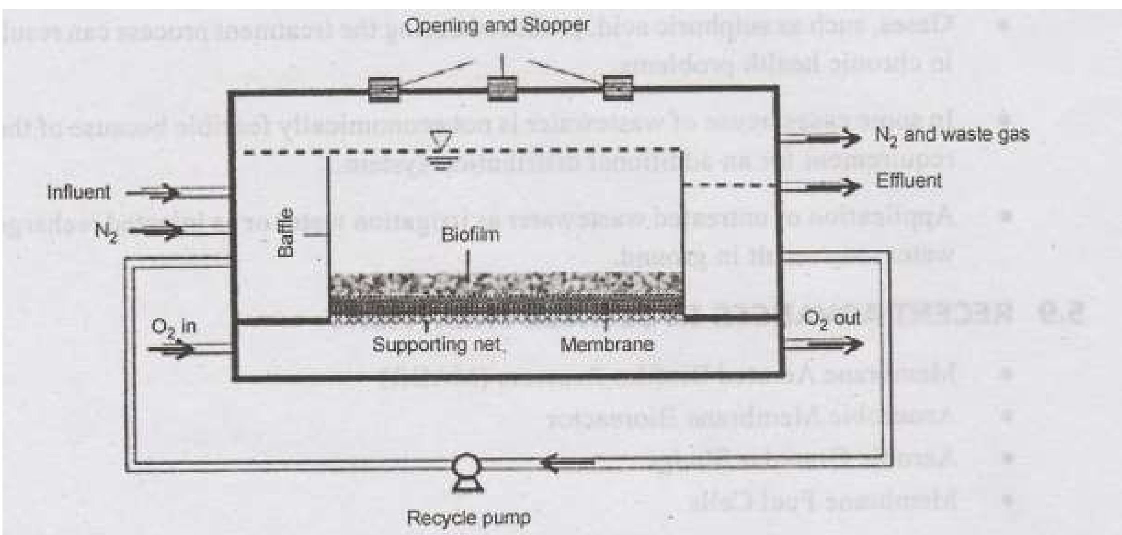


Fig. 5.33 : Membrane Bioreactor

Anaerobic Membrane Bioreactor

An MBR system combines anaerobic digestion with physical separation membranes, resulting in maximum organic load removal and biogas production. The technology produces a superior effluent quality compared to any anaerobic technology on the market.

An MBR is ideally suited for treating wastewater streams or slurries with very high concentrations of organics, solids, and fat, oil, and grease (FOG). The membrane barriers ensure complete solids retention, efficient system operation, and process stability at all times even under peak hydraulic and organic loading conditions. Since gravity settling is not required, higher organic loadings and mixing intensities can be employed than with other anaerobic technologies

To increase loading capacity and improve performance and effluent quality, existing anaerobic systems can easily be upgraded to an An MBR. The system can also be paired with an ADIR aerobic membrane bioreactor (MBR) to provide complete treatment and meet even the strictest discharge requirements.

COST SAVINGS

• Minimize sludge handling and disposal costs\

• Save on energy costs:

• Significantly less energy-intensive than aerobic systems

• Biogas can be utilized to reduce fossil fuel consumption

• Minimize aerobic polishing requirements

• Eliminate primary treatment and wastewater surcharges

• Reduce or eliminate chemical usage

PROCESS ADVANTAGES

• Membrane barrier ensures complete solids retention and process stability

• Large biomass inventory ensures efficient treatment at all times

• Minimal pre-treatment and post-treatment (aerobic polishing) requirements

• Eliminates issues with gravity clarification

• Handles high organic loadings and mixing intensities

• Can digest high amounts of solids and FOG

ENVIRONMENTAL BENEFITS

• Consistent, high quality effluent

• Very low BOD

• Free of TSS

• Continuously meet discharge requirements

• Small footprint

• Convert organic waste to recoverable green energy (heat and power)

• Waste sludge suitable for land application

• Improve local and global water security

SIMPLIFIED OPERATION & MAINTENANCE

• Minimal operator attention

• Reduced sludge handling

• Superior membrane durability and performance with low maintenance:

• Long lifetime

• Simple, infrequent cleaning procedure

• Membranes are cleaned in place

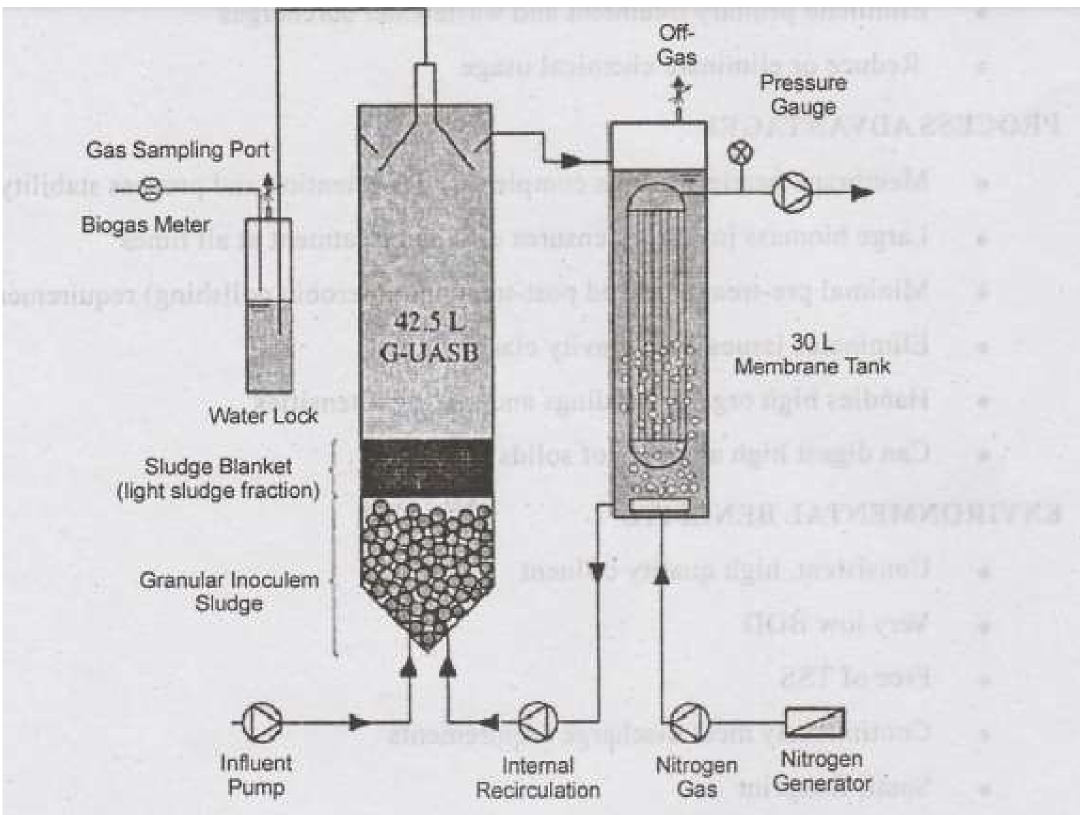


Fig. 5.34 : Anaerobic Membrane Bioreactor

Aerobic Granular Sludge Technology

Aerobic Granular Sludge Technology is an innovative biological wastewater treatment technology that provides advanced treatment using the unique features of aerobic granular biomass. The unique process features of the technology translate into a flexible and compact process that offers energy efficiency and significantly lower chemical consumption.

HOW IT WORKS

Batch Cycle Structure

Based on the unique characteristics of granular biomass, the Aerobic Granular Sludge Technology uses an optimized batch cycle structure. There are three main phases of the cycle to meet advanced wastewater treatment objectives (Fill/Draw, React, Settling). The duration of the phases will be based upon the specific waste characteristics, the flow and

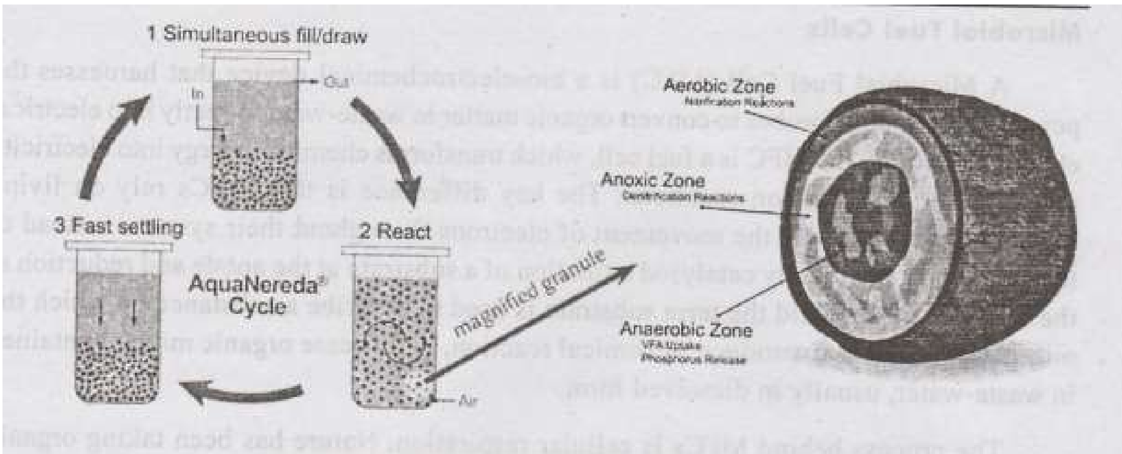


Fig. 5.35 : Aerobic Granular Sludge Technology

FEATURES & SPECIFICATIONS

• Robust structure of granule withstands fluctuations in chemical spikes, load, salt, pH and toxic shocks.

• No secondary clarifiers, selectors, separate compartments, or return sludge pumping stations.

• Settling properties at SVI values of 30-50 mL/g allow MLSS concentrations of 8,000 mg/l or greater.

• Proven Enhanced Nutrient Removal (ENR).

• Simplified operation with fully automated controls.

BENEFITS

• Optimal biological treatment is accomplished in one effective aeration step.

• Four times less space required compared to conventional activated sludge systems.

• Energy savings up to 50% compared to activated sludge processes.

• Robust process without a carrier.

• Significant reduction of chemicals for nutrient removal due to the layered structure and biopolymer backbone of the granule.

• Lowest life-cycle cost.

Microbial Fuel Cells

A Microbial Fuel Cell (MFC) is a bio-electrochemical device that harnesses the power of respiring microbes to convert organic matter in waste-water directly into electrical energy. At its core, the MFC is a fuel cell, which transforms chemical energy into electricity using oxidation-reduction reactions. The key difference is that MFCs rely on living biocatalysts to facilitate the movement of electrons throughout their systems instead of the traditional chemically catalysed oxidation of a substrate at the anode and reduction at the cathode. In this field the term substrate is used to describe a substance on which the microorganism acts to produce a chemical reaction, in this case organic matter contained in waste-water, usually in dissolved form.

The process behind MFCs is cellular respiration. Nature has been taking organic matter substrates and converting them into energy for billions of years. Cellular respiration is a collection of metabolic reactions that cells use to convert nutrients into adenosine triphosphate (ATP), which fuels cellular activity. The overall reaction can be considered an exothermic redox reaction.

In order for a fuel cell to work a complete circuit is needed. In the case of the MFC the cathode and an anode are separated by a cation selective membrane and linked together with an external conductor through the load. When an organic "fuel" is fed into the anode chamber, the bacteria oxidise and reduce the organic matter to generate the life sustaining ATP that fuels their cellular machinery. Protons, electrons, and carbon dioxide are produced as byproducts, with the anode serving as the electron acceptor in the bacteria's electron transport chain.

The electrons pass from the anode to the cathode through the external load connection. At the same time protons pass freely into the cathode chamber through the proton exchange membrane separating the two chambers. Finally oxygen present at the cathode recombines with hydrogen and the electrons from the cathode to produce water, completing the reaction.

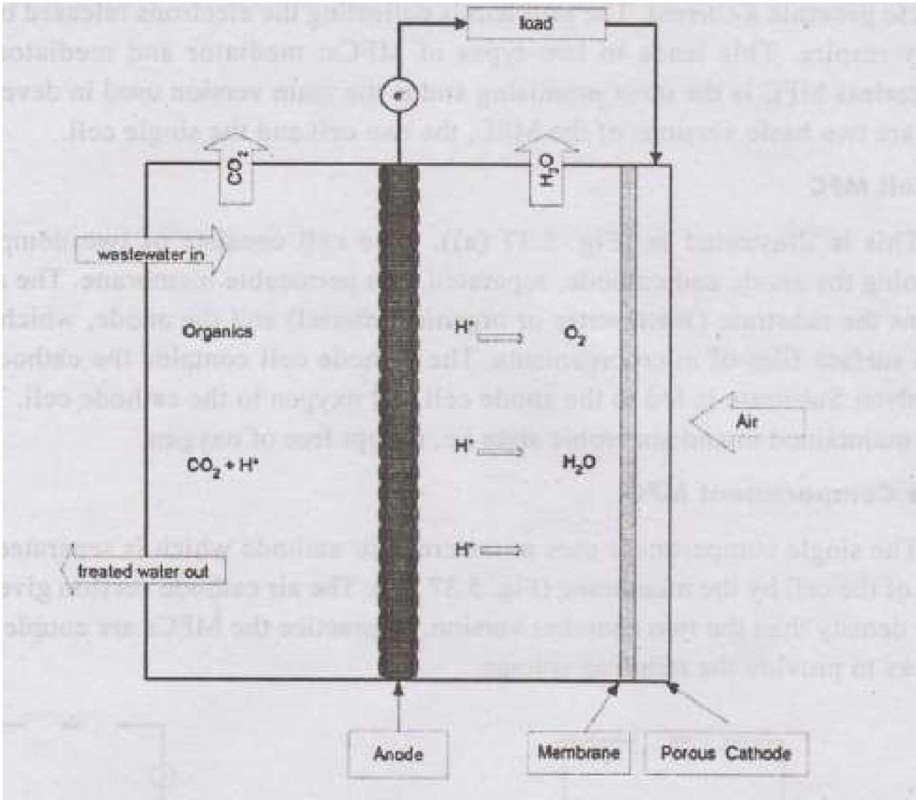


Fig. 5.36 : Microbial Fuel Cells

The use of biological organisms responsible for catalysing electrochemical reactions, gives these systems a level of complexity that is perhaps above that of already complex electrochemical systems (e.g. batteries, fuel cells and supercapacitors). The main differences of MFCs to the conventional low temperature fuel cells are:

• The electrocatalyst is biotic (electroactive bacteria or proteins) at the anode.

• The temperature can range between 15 and 45°C, with close to ambient levels as optimum.

• Neutral pH working conditions.

• Utilisation of complex biomass (often different types of waste or effluent) as anodic substrate.

• A promising moderate environmental impact assessed through life cycle analysis.

MFC construction

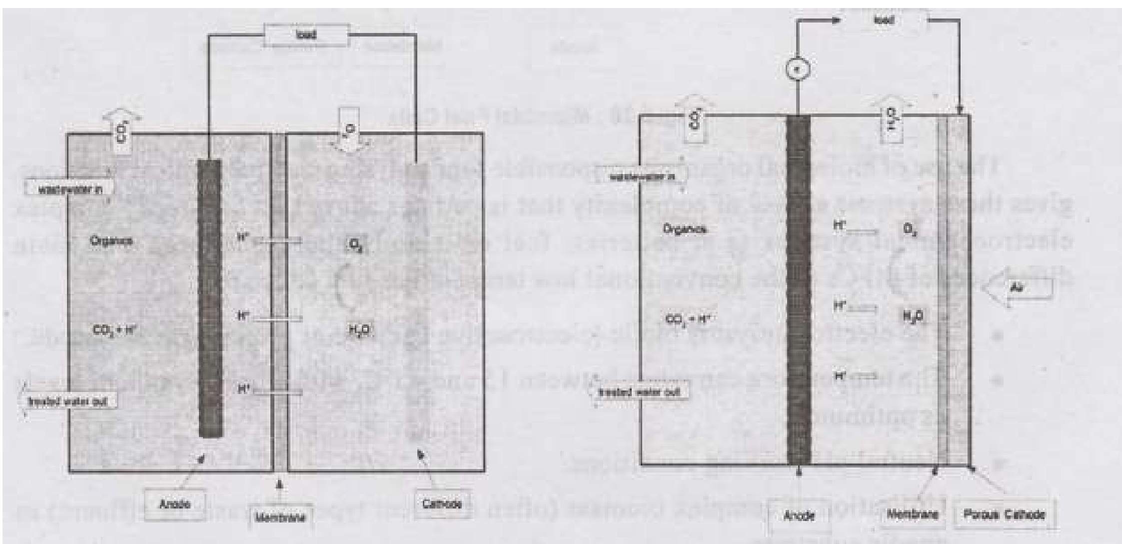
A MFC consists of an anode and a cathode separated by a cation specific membrane. Microbes at the anode oxidise the organic substrate, generating protor.s which pass through the membrane to the cathode, and electrons which pass through the anode to an external circuit to generate a current. The problem is collecting the electrons released by bacteria as they respire. This leads to two types of MFCs: mediator and mediatorless. The mediatorless MFC is the most promising and is the main version used in developments. There are two basic versions of the MFC, the two cell and the single cell.

Two Cell MFC

This is illustrated in (Fig. 5.37 (a)). The cell consists of two compartments, containing the anode and cathode, separated by a permeable membrane. The anode cell contains the substrate (wastewater or organic material) and the anode, which is coated with a surface film of microorganisms. The cathode cell contains the cathode and the electrolyte. Substrate is fed to the anode cell and oxygen to the cathode cell. The anode cell is maintained in and anaerobic state i.e. is kept free of oxygen.

Single Compartment MFC

The single compartment uses an external air cathode which is separated from the inside of the cell by the membrane (Fig. 5.37 (b)). The air cathode version gives a higher power density than the two chamber version. In practice the MFCs are coupled together in stacks to provide the required voltage.



(a) : Two Cell Compartment (b) : Single Compartment MFC

MFCS and Waste-Water Treatment

All types of waste-water containing organic matter can be treated by this process, including domestic waste-water, brewery effluent, and much else. Several plants are in operation and have shown good results. Use of MFCs for waste-water requires a design which allows the waste-water to flow through the cell over the anode surface. Various configurations have been adopted for this purpose, including the tubular MFC where the cathode is placed on the outside of the tube and the anode occupies the full internal space. Waste-water flows through the anode from one end to the other.

MFC reactions

The mechanism of oxidation and reduction in the MFC is not clearly understood, and various reactions have been proposed to explain the process. An example using acetate as the substrate follows:

Anode:	$CH_3COOH + 2H_2O \rightarrow 2CO_2 + 8e^- + 8H^+$	....	(1)
Cathode:	$2O_2 + 8e^- + 8H^+ \rightarrow 4H_2O$	....	(2)
Overall:	$CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O + \text{Electricity}$	....	(3)

CONSTRUCTION, OPERATION AND MAINTENANCE ASPECT

Maintenance Scheduling

• Maintenance of each equipment is done as the recommendations of manufacturer.

• A History card is maintained for each equipment so that record is maintained for equipment performance and maintenance.

• Good housekeeping is an important aspect of plant operation.

Pumping Machinery

• To run the machinery in a way so as to have free fall from invert of sewer.

• Mostly 2 or 3 pump sets are out of order.

• Minimum one pump be operated during night hours so that sewers are empty in Hiw z morning.

• Guide Wire/ Guide Rail should be in good condition.

Screening Chamber & Wet Well

• Regular Cleaning

• Disposal of Screenings

• Washing of Bar Screens

• Washing sludge layer from walls using waterjet

• Desilting of wet well once a year.

Cleaning Chamber & Fine Screens

• Should be sccured minimum once in a week.

• Fine Screens should be kept clean of all obstructions. If the screen are of mat type, its operation should be adjusted such that a mat is always on the screen.

Grit Channel

• (1W+18) grit channels for peak flow.

• Should be used one at a time, alternatively everyday.

• Should be cleaned everyday.

• Proper & efficient removal of silt in grit channel will improve the functioning of treatment.

Proportional Weir

• It is provided to maintain uniform flow on upstream and downstream of gritchannel.

• Must be calibrated so as to show the quantity offlow.

• Flow be recorded every hour. In SBR Plants the flow recording graphs are recorded in SCADA

Distribution Channel

• Must be cleaned every day.

Moving Bed Biofilm Reactor (MBBR)

The STP is said to be running successfully, if:-

• The biofilm layer shall accumulate on the biomedia.

• The flocs should generate in clarifier.

• The smell of sludge should not be foul.

• When starting the plant initially, the air blowers should be operated for passing the air through diffusers and run continuously,otherwise the desired parameters will not be achieved.

• Fill both aeration tanks to the normal operating sewage depth, thus allowing the aeration equipment to operate at maximum efficiency.

• Using all of the aeration tanks will provide the longest possible aeration time.

• The effluent end of the aeration tank should have a dissolved oxygen level of at least 1.0 mg/L. DO in the aeration tank should be checked every two hours. Generally the DO is approx. above 4 in aerated sewage.

• The COD reduction in treated sewage Vs. raw sewage cannot be less than BOD reduction.

How to check DO in Aeration Tank

The presence of DO in aeration tank requires the elaborate procedure of using a meter operated electronically and keeping the probes well cleaned at all times. This is not always possible. Moreover, typical plant control requires an answer to the question of whether residual DO is present or absent in the secondary clarifier overflow. This can be easily carried out in the field as follows:

1. Take a 10 ml well washed test tube.

2. Hold it gently against the weir overflow sideways.

3. Allow the sewage to fill the tube and overflow for a few minutes.

4. Gently take the tube and pour out about 2 ml.

5. Add few drops of manganous sulphate solution.

6. Add a few drops of potassium iodide solution.

7. Close the top with the thumb and invert a few times.

8. Allow to stand for a few minutes.

9. If there is a yellow precipitate, DO is present.

10. If there is a white precipitate, there is no DO.

• With help of electronic instrument.

• Online sensors are required to be provided.

Reactors/SBR

• 2 in nos. (parallel & in series).

• The problem of foam can be solved using water jet.

• Reactors should be desludged every day to maintain proper MLSS.

• The walls, walkway and the railing to be washed daily using waterjet.

STANDARDS FOR DISPOSAL

Table 4.1 BIS (ISI) Standards for Discharge of Sewage and Industrial Effluents in Surface Water Sources and Public Sewersns

S. No.	Characteristics of the Effluent	Tolerance Limit for Sewage Effluent Discharged into Surface Water Sources as per IS 4764-1973	Tolerance Limit for Industrial Effluents Discharged into	
			Inland surface waters, as per IS 2490-1974	Public sewers as per IS 3306-1974
(1)	(2)	(3)	(4)	(5)
1.	BOD_5	20 mg/l	30 mg/l	500** mg/l
2.	COD	–	250 mg/l	–
3.	pH value	–	5.5 to 9.0	5.5 to 9.0
4.	Total Suspended Solids (TSS)	30 mg/l	100 mg/l	600 mg/l
5.	Temperature	–	40°C	45°C
6.	Oil and Grease	–	10 mg/l	100 mg/l
7.	Phenolic compounds (as Phenol)	–	1 mg/l	5 mg/l
8.	Cyanides (as CN)	–	0.2 mg/l	2 mg/l
9.	Sulphides (as S)	–	2 mg/l	–
10.	Fluorides (as F)	–	2 mg/l	–
11.	Total residual chlorine	–	1 mg/l	–
12.	Insecticides	–	Zero	–
13.	Arsenic (as As)	–	0.2 mg/l	–
14.	Cadmium (as Cd)	–	2 mg/l	–
15.	Chromium, hexavalent (as Cr)	–	0.1 mg/l	2 mg/l
16.	Copper	–	3 mg/l	3 mg/l
17.	Lead	–	0.1 mg/l	1 mg/l
18.	Mercury	–	0.01 mg/l	–
19.	Nickel	–	3 mg/l	2 mg/l
20.	Selenium	–	0.05 mg/l	–
21.	Zinc	–	5 mg/l	15 mg/l
22.	Chlorides (as Cl)	–	–	600 mg/l
23.	% Sodium	–	–	60%
24.	Ammoniacal Nitrogen (as N)	–	50 mg/l	50 mg/l
25.	Radioactive Materials (i) α-emitters	–	10^{-7} μC/ml (micro curie/ml)	–
	(ii) β-emitters		10^{-6} μC/ml	–

* Includes Rivers, Estuaries, Streams, Lakes and Reservoirs.

SLUDGE CONDITIONING AND DEWATERING

• Done to improve dewatering characteristics of sludge.

Methods:

(i) Chemical Conditioning,

(ii) Heat Treatment.

(i) Chemical Conditioning

• Done for raw or digested sludges.

• Chemical like alum, polyelectrolytes, ferric or aluminium salts, lime, ferric chloride are added.

• These chemicals make the sludge particles agglomerate and become denser. Charge neutralisation occurs between particles and they form a rigid and porous lattice structure and permits escape of water.

• The choice of chemicals depends on pH, temperature and ash content of sludge.

• Optimum dosage of ferric chloride and alum is 1 kg/m3 of sludge.

• Digested sludge because of high alkalinity requires huge chemical demand and therefore the alkalinity has to be reduced to save on the chemical. This is achieved by elutriation.

• Elutriation is the physical washing of sludge with low alkalinity water which reduces the chemical demand.

• Elutriation is done before chemical conditioning. The methods of elutriation

(a) Single-stage go ba

(b) Multi-stage

(c) Counter-current washing.

• The quantity of washing water required depends on the method adopted and hing water required depends on t alkalinity of sludge.

• Single stage washing requires 5 times more water than the counter-current and sbivog is therefore used only for small plants.

• The sludge and digestion water are mixed in a chamber using mechanical arrangements for a detention period of 20 seconds. The sludge is then settled in settling tanks and excess water is decanted.

• In counter-current washing, (single or multi-stage), the sludge and dilution water flow into the tank from opposite directions.

• The volume of wash water required is twice or thrice the volume of sludge elutriated.

• Physical unit operation used to reduce moisture content of the sludge and thus increase the solids concentration.

Methods:

(i) Air Drying in sludge drying beds.

(ii) Mechanical means - Vacuum filtration

- Centrifugation bab

- Pressure filtration

Purpose of Dewatering:

(i) Cost of transportation of sludge to ultimate disposal site is reduced (volume To reduction).

(ii) Ease in handling dewatered sludge.

(iii) Increase in calorific value of sludge. Incineration cost is less due to moisture reduction.

(iv) Rendering sludge odourless and non-putrescible.

(v) Reduce leachate production when disposed in landfills.

Sludge Drying Beds

• Suitable for locations where temperature is high (India).

• Sludge is applied on specially prepared open beds of land. (c)

• A sludge bed consists of bottom layer of gravel of uniform size and depth 30 cm over which is laid a bed of clean sand of depth 15 to 30 cm.

• Clean sand of effective size of 0.5 to 0.75 mm and uniformity co-efficient not greater than 4 is placed over the gravel.

• Open jointed pipes are provided as under drains in gravel layer to provide drainage to the liquid that passes through the sand and gravel layers. •

• Under drains are made of vitrified clay of atleast 10 cm o at a spacing of 6 m apart.

• Graded gravel is provided around the under drains in layers upto 30 cm with a minimum of 15 cm above the top of under drains.

• Drying beds adopted are 6 to 8 m wide and 30-45 m long.

• Minimum of two drying beds should be provided

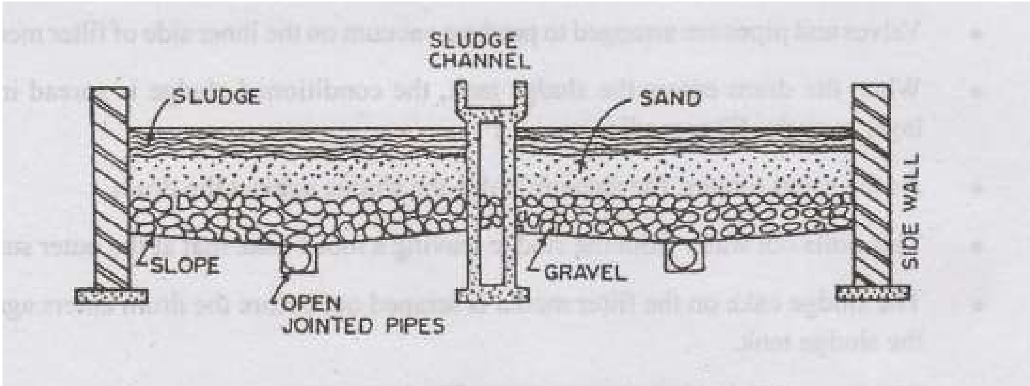


Fig. 5.38 : Sludge Drying Beds

• The area needed for dewatering digested sludge is dependent on total volume of sludge, climate, temperature and location.

• Sludge should be deposited evenly to a depth of not greater than 20 cm.

• When digested sludge is deposited on a well drained bed of sand, the dissolved gases tend to buoy up and float the solids leaving a clear liquid at the bottom which drains through the sand rapidly.

• Major portion of liquid drains off in few hours and evaporation starts. The sludge cakes shrink.

• With good drying condition, the sludge will dewater and become fit for removal in 2-3 weeks with volume reduction of 20 to 40%.

• Dried sludge cake is removed by showel when moisture is less than 70%.

• Pick up trucks are used for hauling of sludge cakes.

Mechanical Methods:

• Vaccum Filtration (common)

• Filter Press

• Centrifugation

• Chemical conditioning is normally done prior to mechanical dewatering.

• Used to dewater raw or digested sludges.

Vacuum Filters:

• Vaccum filter consists of cylindrical drum over which is laid a filter medium of wool, cloth, synthetic fibre, plastic, stainless steel (mesh) (or) coil spring.

• The drum is suspended horizontally so that one half is submerged in sludge tank.

• Valves and pipes are arranged to produce vacuum on the inner side of filter medium.

• When the drum enters the sludge tank, the conditioned sludge is spread in thin layer over the filter media.

• As the drum rotates, the vacuum holds the sludge against the drum.

• This pulls out water from the sludge leaving a moist cake mat at the outer surface.

• The sludge cake on the filter media is scraped out before the drum enters again in the sludge tank.

• The rate of filtration is 10 to 50 kg/m2/hr.

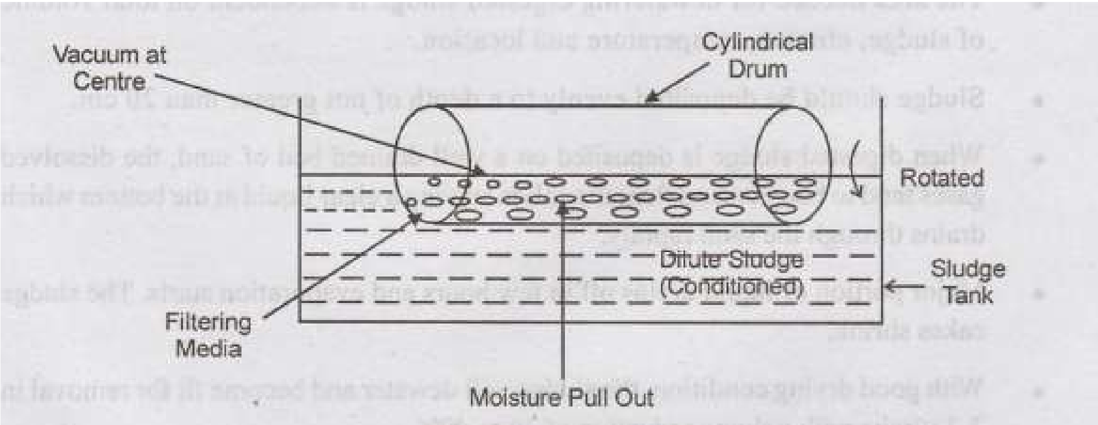


Fig. 5.39 : Vacuum Filter

ULTIMATE RESIDUE DISPOSAL

• Sludge (Wet/Dry/Incinerated) is disposed by the following methods:

(i) Spreading on farm land

(ii) Dumping

(iii) Land filling

(v) Incineration

(iv) Sludge lagooning

(vi) Disposal in water or sea.

(i) Spreading on Farm Land

• Dewatered sludge is disposed by spreading over farm lands and after drying the soil is ploughed.

• Wet dewatered sludge can be injected directly into soil by digging shallow trenches, 1918w bru 50 to 90 cm width, 0.3 to 0.4 m deep and 1 to 1.5 m C/C spacing. After the water evaporates, the trenches are covered with dry earth.

• After one month, the land is ploughed for cultivation.

• The sludge is a source of nutrients, nitrogen and phosphate and improves soil fertility.

• The sludge humus increases the water holding capacity of soil.

• Sludge acts as soil conditioner and reduces soil erosion.

(ii) Dumping

• The stabilised sludge, digested sludge, clean grit, incinerator residue that will not cause pollution or nuisance can be disposed in abandoned mines or quarry.

• The sludge may also be dumped into sea, where cities are located near sea shores and where such wind direction prevail which will discharge the sludge deep into sea.

(iii) Land Filling

• Sanitary landfills can be used to dispose off the sludge, grease, grit and solids both stabilised and not stabilised.

• To reduce transportation cost, it is better to dewater the residues.

• Sludge waste is deposited in designated area of landfills, compacted with tractor/ roller and covered with 30 cm soil.

• Safety measures have to be taken to prevent any pollution of surface or ground waters

(iv) Sludge Lagooning

• A lagoon is a shallow earthern basin into which untreated or digested sludge is deposited.

• The untreated sludge undergoes anaerobic or aerobic decomposition and may release objectionable odours. So the lagoons should be located away from towns.

• The depth of lagoon is 0.5 to 1.5 m, detention time is 1 to 2 months.

• Under drainage system is provided at the bottom.

• It works on fill and draw basis.

• After stabilisation or evaporation, the lagoon contents are dugout to half the volume and used as manure.

• Lagoons are used for storage + digestion + dewatering + disposal in isolated locations where the soil is not porous and there is no chance of ground water contamination.

• Cost is less, but cause ugly sight, odours and mosquito breeding.

• Used as emergency storage when digesters are under repair.

(v) Disposal by Incineration

• The dewatered wet sludge may be disposed by burning at very high temperatures inside incinerators.

Types of Incinerators

(i) Multi-hearth furnace.

(ii) Flash-type of furnace.

(iii) Fluid-bed furnace.

• The end product is ash which is harmless and can be disposed in low-lying areas, sea, water, abandoned mines etc.

(vi) Disposal in Water or Sea

• Not commonly adopted.

• Used where large volume of water is available for dilution.

• Sludge is barged into deep sea for proper dilution and dispersion.

• The outfall/disposal end should be carefully designed to prevent coastal pollution and navigation problems.

Water Supply And Wastewater Engineering: Unit V: Sewage Treatment And Disposal: Two Marks Questions And Answers

TWO MARK QUESTION AND ANSWERS

1. What are the types of trickling filters?

• Conventional trickling filter

• High rate trickling filter

2. What are the operational troubles in trickling filter?

• Fly nuisance

• Odour nuisance

• Ponding troubles

3. Define sludge age.

The sludge age is defined as the average time for which particles of suspended soil remain under aeration.

4. Define sludge volume index.

Sludge volume index is defined as the volume occupied in ml by 1 gm of solids in the mixed liquor after settling for 30 minutes and is determined experimentally.

5. What are the methods of disposing the sewage effluent?

• Disposal in water (dilution)

• By disposal on land

6. What are the different types of sewage treatment?

• Contact beds

• Intermittent sand filters

• Trickling filters

• Miscellaneous type of filters

7. Define sludge digestion

The sludge is first stabilized by decomposing the organic matter under controlled anaerobic condition. The process of stabilization of the sewage particles are called sludge digestion

8. What are the stages in the sludge digestion process?

• Acid fermentation

• Acid regression

• Alkaline fermentation

9. What is meant by ripened sludge?

The ripened sludge is nothing but the digested sludge is collected at the bottom of the digestion tank and it is alkaline in nature.

10. What are the factors affecting sludge digestion and their control?

• Temperature

• pH value

• mixing and stirring of raw sludge with digested sludge

11. What are the types of incinerators has primary designed?

• Multiple hearth furnaces

• Fluid bed furnace and infra red furnace

12. What are the methods of aeration?

• Diffused air aeration

• Mechanical aeration

• Combined aeration

13. What is meant by sludge concentrator unit?

The sludge obtained in a sludge digestion plant contains too much of moisture and is therefore very bulky may be reduced in its moisture content by sending into sludge thicker unit (or) sludge concentrator unit

14. Give different types of thicker unit.

• Gravity thickener

• Floating thickener

• Centrifugal thickener

15. What is Coagulation?

The fine mud particles and other colloidal matter present in waste waters gets absorbed in flows, forming the bigger sized flocculated particles. The process of bolla addition and mixing of chemicals is called coagulation.

16. What is biological treatment?

Biological treatment is carried out by changing the character of the organic matter, and thus converting it into stable forms (like nitrates, sulphates) by oxidation or nitrification.

17. What is biological film (or) slime layer.

As the sewage percolates through the filtering media, fine colloidal organic matter to mois trapped in the voids between the particles of the filtering media.

18. What is sloughing?

The break up or detachment of the biomass (biological solids) from the slime layer is known as sloughing.

19. What are the methods of disposal of septic tank effluent?

• Soil absorption system

• Biological filters

• Up flow anaerobic filters feesn

20. Define percolation rate.

Peculation rate is defined as the time in minuets required for sewage of water through that ground by one cm.

21. What are the soil absorption system?

• Dispersion trench

• Seepage pit (or) soak pit

22. What is meant by de oxygenation curve?

The curve which represents (or) showing the depletion of D.O with time at the given temperature.

23. What are the methods of applying sewage effluents to forms?

• Surface irrigation

• Free flooding

• Border flooding

• Check flooding

24. Name the biological zone in lakes.

• Euphonic zone

• Littoral zone

• Benthic zone.

25. What is meant by re -oxygenation?

In order to counter balance the consumption of D.O due to the de- oxygenation, atmosphere supplies oxygen to the water and the process is called the re-oxygenation.

26. What is meant by oxygen sag curve?

The amount of resultant oxygen deflect can be obtained by algebraically adding the de -oxygenation and re -oxygenation curves. The resultant curve so obtained is called oxygen sag curve.

27. What is meant by zone of recovery?

The zone in which the river water tries to recover from its degraded conditions to its former appearance is called zone of recovery.

28. What is meant by sewage sickness?

The phenomena of soil getting clogged when the sewage is applied continuously on a piece of land is called sewage sickness.

29. What are the preventive methods for sewage sickness?

• Primary treatment of sewage

• Choice of land

• Under drainage of soil

• Giving rest to land and Rotation of crops

30. Define dilution factor.

The dilution factor is defined as the ratio of the amount of river water to the amount of the sewage.

31.What is meant by self purification?

The automatic purification of natural water is known as self purification.

32. List various natural forces of self purification.

• Physical forces

• Chemical forces

MODEL QUESTION PAPER - I

PART A

1. State the various reasons for water demand in the recent times.

The various reasons for water demand in the recent timer are:

i) Climatic conditions

ii) Expansions of the city limits

iii) Increase in population

iv) Quantity of water available for domestic purposes

v) System of sanitation

2. State the factors governing the selection of particular water source.

The factors governing the selection of a particular water sources are :

i) Quantity of available water sufficient to meet the demand throughout the year.

ii) Quality of available water.

iii) Distance of source of supply

iv) Topography of intervening area.

v) Elevation of source.

3. Highlight the criteria required for the pipe materials in the water supply system.

Following are the basic criteria's required for a pipe material in a water supply system.

i) A good pipe material should be capable of withstanding internal and external pressures.

ii) A good pipe material be easily jointed.

iii) A good pipe material should be durable.

iv) A good pipe material should not react with water.

v) Head loss due to friction should be minimum

4. What are flocculators?

Flocculators are generally rectangular tanks with paddles operated by electric motors. The paddles rotate at 2 to 3 rpm. speed. The purpose of the flocculator is to facilitate to 'floc' formation. The flocculator provides energy and gentle mixing to induce particle collisions that form large flocs.

5. Distinguish between Ultrafiltration and Nanofiltration.

Ultrafiltration

Ultrafiltration are microprocess membranes which remove suspended small size particles by physical separation.

They are low pressure processes.

Nanofilteration

Nanofilteration remove dissolved salts ions by osmosis.

Nanofilteration is also a low pressure reverse osmosis.

6. Mention the the important components needed for the water distribution to buildings.

i) Valves

a) Sluice valve, b) Check valves, c) Air valves, d) Drain valves

ii) Ferrule

iii) Goose neck

iv) Seevice pipe

v) Stop cock

vi) Water meter

vii) Water taps

7. Define BOD.

Biological Oxygen Demand: Measure of oxygen required to oxidise biologically active basa ve organic matter in sewage by micro-organisms.

Significance of BOD:

1. Quantity of O2 required for biological stabilization of organic matter in sewage.

2. Size of treatment facilities.

3. Measure of efficiency of treatment

8. What are small bore systems?

Small bore sewer is a water tight small diameter waste water collection pipe that provides servicing with superior operational and environmental performance at a significance lower cost as compared to conventional gravity sewage.

9. What is meant by sludge volume index?

Slude volume index is defined as the volume occupied in ml by 1 gm of solids in the mixed liquor after settling for 30 minutes. Sludge volume index indicates the sludge concentration in system and settallility characteristics of sludge.

10. What is meant by sludge conditioning?

Sludge conditioning is a treatment process which improves the drainability of digested sludge. The addition of chemical such as alum, poly electrolyles, ferric salt to improve the dewatering characteristic of sludge is called as sludge conditioning.

PART B

11. a) Describe in detail about the hydraulics of flow in pipes.

Refer Section 1.2

b) (i) Write down the water quality standards for drinking purpose as per B.I.S.

Refer Section i.6.1

(5)

(ii) Discuss, the factors influencing the selection of a pump. viral

Refer Section 1.7.

12. a) Explain about the process carried out in sedimentation tanks and sand filters during water treatment operation.

Refer Section 2.1

(b) (i) Explain the design principies of flash mixer and flocculator.

Refer Section 2.3

(6)

(ii) Design a clarifier for a population of 60000 persons. Percapita demand is 150 Lpcd. Peak demand 180% of average demand. Assume suitable data if necessary.

(7)

Refer Section 2.4

13. (a) Brief about few recent and possible advancement in water filtration techniques.

Refer Section 2.12

(b) Elaborate how are defluoridation and demineralization carried out in the advanced water treatment process?

Refer Section 2.10

14. (a) Explain various systems of sanitary plumbing and write down their main characteristics of each system.

Refer Section 4.16

14. (b) Expand UASB and draw the schematic diagram of UASB. Given that the influent to UASB reactor has following characteristics: flow rate = 8000 m3/day, depth of sludge blanket = 2.2 m, reactor height (including settler) = 5 m, effective coefficient (ratio of sludge to total volume in sludge blanket) = 0.85, and average concentration of sludge = 70 kg/m3. Determine HRT and reactor area. Take BOD removal efficiency as 80% and sludge age as 30 days.

Refer Section 5.5

15. (a) What do you mean by sludge thickening process? Explain Gravity thickening and air flotation unit with a neat diagram.

Refer Section 5.12

(b) Draw a neat sketch of a high rate two-stage anaerobic sludge digster and explain its working principle.

Refer Section 5.2

PART C

16. (a) Briefly discuss about the various physic-chemical test on water and write their limitation for domestic and industrial purpose.

Refer Section 5.12

(b) It is preposed to treat 18 ML/d of primary treated sewage with the help of a ASP system. The BOD of raw sewage is 280 mg/L. Design the various components of ASP system by assuming the following parameters.

MLVSS in the reactor = 2500 mg/L

Return sludge Concentration (VSS)= 800 mg/L

MCRT = 8 d

Yield coefficient = 0.45

Decay coefficient =0.05 d-1

Refer Section 5.2

MODEL QUESTION PAPER - II

PART A

1. Write in brief about recharge of ground water.

Groundwater recharge (or) deep drainage is a hydrologic process where water moves downward from surface water to groundwater. Groundwater recharge is the primary method through which water enters on Aquifer. Ground water recharge also encompasses water moving away from the water table farther into the saturated zone.

2. List functions of intake structures.

The main function of intake is to provide highest quality of water from source.

To protect pipes and pumps from damaging (or) clogging by wave action/ floating bodies and submerged aquatic lives.

To help in safely withdrawing water from the source over predetermined pool levels and then to discharge this water into the withdrawal conduit.

3. Mention the basic for the selection of types and capacity of pumps.

Reciprocating pumps	Centrifugal pumps
i) ***Discharge*** Pulsating flow and has a constant discharge under varying heads.	i) ***Discharge*** Continuous flow and does not give constant discharge under variable head.
ii) ***Speed*** Low speed less than 30m/min.	ii) ***Speed*** High speed (500 - 1000 rp)
iii) ***Head*** Can work at high heads.	iii) ***Head*** Suitable for low head.

4. Write the nature of any four coagulants.

i) Alum

Most common and universal coagulant. Alum requires presence of alkalinity in water to form floc. Alum dissolves in water hyderolyze into aluminium hyderoxide. The aluminium hyderoxide floc so formed in insoluble in water. Alum reduces turbidity, taste and odour. It produces crystal clear water.

ii) Chlorinated Copperas:

Hydrated ferrous sulphate is called copperas. Copperas are effective in removing colour. Ferric chloride is effective over pH 3.5 to 6.5 and above 8.5.

iii) Ferrous sulphate and lime:

Lime is added with ferrous sulphate to increase the reaction rate. The ferric hydroxide is a heavier floc. Ferrous sulphate is effective at a pH range above 8.5 Agin 000 abiloa babnis

iv) Magnesium Carbonate and lime

When magnesium carbonate and lime are dissolved in water, magnessium hyderoxide, Calcium carbonate is formed. Both Mg(OH), and CaCO, are soluble in water resulting in formation of sludge which is slurry.

5..Distinguish between Ultrafiltration and Nanofiltration.

Ultrafiltration	Nanofilteration
Ultrafiltration are microprocess membranes which remove suspended small size particles by physical separation.	Nanofilteration remove dissolved salts ions by osmosis.
They are low pressure processes.	Nanofilteration is also a low pressure reverse osmosis.

6. Mention the the important components needed for the water distribution to buildings.

i) Valves

a) Sluice valve, b) Check valves, c) Air valves, d) Drain valves

ii) Ferrule

iii) Goose neck

iv) Seevice pipe

v) Stop cock

vi) Water meter

vii) Water taps

7. State the discharge standards for any two parameters for treated sewage.

Tolerance limit for industrial effluents discharge into public sewers as per IS 3306-1974

(i) BOD5 -m500 mg/L

(ii) COD - --

(ii) pH value - 5.5 to 9.00

(iv) Total suspended solids - 600 mg/L

(v) Chromium – 2mg/L

8.What do you mean by UASB?

Uplow Anaerobic sludge Blanket: It is an anaerotric reactor in which sewage flaws upward through the sludge led (or) aggregates. The UASB reactor maintains a high concentration of biomass through the formation of highly settleable microbial sludge aggregate.

Some of the merits are:

(i) Three phase (gas-liquid-solid) seperation

(ii) Biogas recovery

(iii) Sludge granules acts like a filter media.

9. How do you remediate sewage sickness.

The remedial measures for sewage sickness.

(i) Primary treatment of sewage

(ii) Choice of land

(iii) Under-drainage of soil

(iv) Giving rest to the land

(v) Rotation of crops

(vi) Applying sewage to shallow depths.

10. What is meant by sludge conditioning?

Sludge conditioning is a treatment process which improves the drainability of digested sludge. The addition of chemical such as alum, poly electrolyles, ferric salt to improve the dewatering characteristic of sludge is called as sludge conditioning.

PART B

a) Give a detailed account on the selection of pumps and pipe materials suitable for the conveyance system.

Refer Section 3.9

b) 12. (b) What is intake structure? Explain with neat sketches, the various type of intake structures based on sources.

Refer Section 1.7

12. a) Describe in detail about the principle and mechanism of desalination process.

Refer Section 2.12

(b) (i) Explain the design principles of flash mixer and flocculator. (6)

Refer Section 2.3

(ii) Design a clarifier for a population of 60000 persons. Percapita demand is 150 Lped. Peak demand 180% of average demand. Assume suitable data if necessary. (7)

Refer Section 2.4

13. (a) Find the flow in each pipe in the Loop shown in Fig. 15 (a). Use Hardy Cross method for analyzing the Loop. Consider CH as 1 10 for all pipes.

Refer Section 3.6

(b) Explain the important aspects associated with the house service connection.

Refer Section 3.10

14. (a) Enumerate and explain the various physico-chemical characteristics of sewage and state their environmental significance.

Refer Section 4.3 and 4.5

(b) From a topographic map and field survey, the area of the drainage basin upstream was found out to be 35 hectares. Determine the maximum rate of run-off for a 10 year. The length of overflow slope is 45 meter with an average overland slope of 2%. The length of main basin channel is 700 meter with a slope of 1.8%. Ratio of area and perimeter is found out to be 0.6 meters. Take mannings roughness coefficient to be 0.09 and total runoff coefficient to be 0.35

elei Refer Section 4.7

15. (a) Design a high rate trickling filter from the following data:

Design flow - 40 ML/d

Recirculation ratio -1.5

BOD of raw sewage - 250 mg/L

Desirable effluent BOD - 20 mg/L

Refer Section 5.3

(b) Write short notes on lagooning dumping landfilling and incineration fo solid wastes.

Refer Section 5.13

PART C

16. (a) Design the rapid gravity sand filter for a flow of 20 MLD. Assume suitable design parameters.

Refer Section 5.2

(b) A waste treatment plant is required to digest a sludge in such a way that gig lie the moisture content is reduced to 95% from the initial value of 96%. The inflow of sludge initially contains 70% volatile matter in the solid portion and during digestion only 60% of the volatile matter is destroyed. The specific gravity of volatile matter is 1.2 and that of fixed solid is 2.5. Calculate the volume of sludge before and after digestion if the inflow contains 2500 kg dry solids per day. Assuming 100 kg/m2/year solids loading rate, design the sludge drying bed required for dewatering 10 zoites operation.

Refer Section 5.12