MODULE -1

Introduction to environmental engineering-Sources of watersupply-Water demand-Quantification of water demand through population forecasting–Factors affecting consumption – Fluctuations in demand

SOURCES OF WATER

INTRODUCTION

Water source get their water from precipitation. Major Precipitation are Rain, Snow, Hail and Dew. Major Source of water available on earth are:

1. Surface source-water available at the ground surface.

2. Sub-surface source (underground water)-exist below ground level.

SURFACE SOURCE:

Water is available at the ground surface. Water flows over the surface of earth. They are directly available for water supplies

- Ponds and lakes
- Streams and rivers
- Storage reservoirs
- Oceans (not commonly used for water supplies)

a) Ponds and lakes:

- Natural depression formed within the surface of earth filled with water
- Pond-small depression
- Lake-large depression
- **Quality of water** – Good quality, no need of much purification
- Still water of lakes and ponds-algae, weed and vegetable growth takes place imparting bad smells, tastes and colours
- **Quatity of water-**small

- Depends on catchment area, annual rain fall and geological formations
- Not considered as the principal source
- Used for small town and hilly areas

b) Streams and rivers:

- Large streams are used as source of water by providing storage reservoir, barrage etc. across them.
- Rivers-Most important source of water supply
- Rivers may be perennial or non-perennial
- Perennial rivers are those in which the water is available throughout the year. it can be used as source of public supplies directly
- Non- perennial rivers, the weir or barrage or low dam may be constructed to form a storage reservoir .
- River can be used directly or by providing storage
- **Quality**-Not reliable as it contains large amount of silt sand suspended matter
- River water must be properly analysed and well treated before supplying to public

c) Storage reservoirs:

- A water supply scheme drawing water directly from a river or a stream may fail to satisfy the consumers demand during extremely law flows
- While during high flows, it may again difficult to carry out its operations due to floods.
- A pool or artificial lake formed on the upstream side of the barrier constructed across the river
- Main source of water supply for big cities
- **Quality** is same as the natural lake
- Eg: Dam

QUALITY AND QUANTITY OF SURFACE WATER:

Quality: Surface water is generally contaminated and cannot be used without treatment it may contaminated by:

- Gases and dusts from atmosphere get added to the rain water
- Sewage and industrial water get added to the water
- Inorganic impurities like silt, clay, etc. get added due to erosion
- Organic impurities get added in the form of vegetable washings. Dead matters etc.
- Algae, weed and other plant growth in still water imparting bad smells, tastes and colours

Quantity: Depends upon the rainfall. May too high and may be too less

SUB-SURFACE SOURCE (UNDERGROUND WATER)

- It exist below the ground level
- Water stored in the underground reservoir through infiltration
- They are generally pure due to the filtration during percolation
- These are less affected by bacteria
- But these are rich in dissolved salts, minerals, gases etc

The underground water is brought to the surface by:

- Springs
- Infiltration galleries
- Infiltration wells
- Wells and tube wells

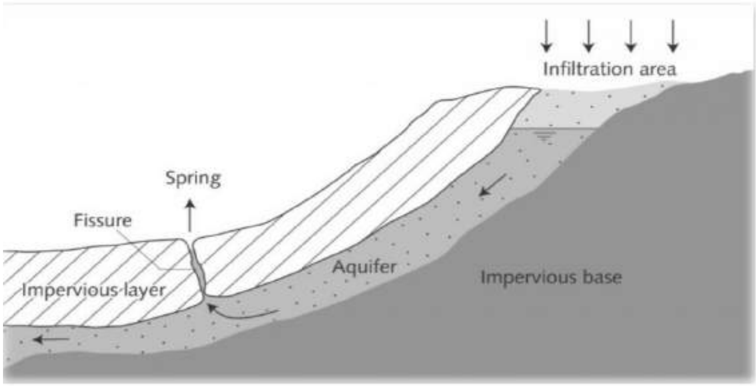
Springs:

- Natural outflow of the ground water at the earth surface.
- The water of the spring may contain some type of salt or minerals
- So it should be tested before use
- This source is suitable for water supply in hilly town
- The following are the different types of springs

  1.Artesian spring

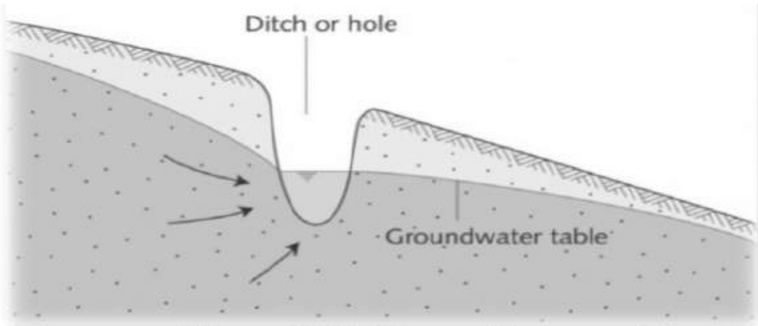
  - It occur when the ground water , under pressure, finds its way to the land surface (as shown in below figure)

- The spring flows because the pressure in the aquifer , which is covered by a confining layer, is greater than atmospheric pressure at the land
- Some artesian springs discharge Hot water. such springs are termed as hot springs



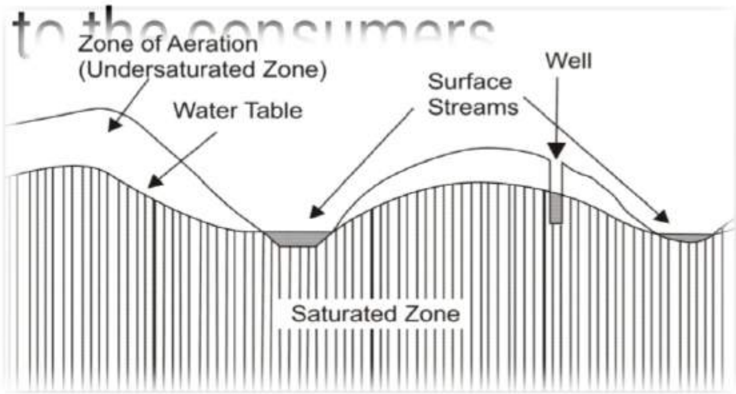
2. Gravity spring

- The gravity spring comes into existence when the water table rises along the hill slope and the water finds a path on the slope through which it rushes out by gravity
- The discharge of water from such springs is variable as the water table may rise or fall in different seasons.



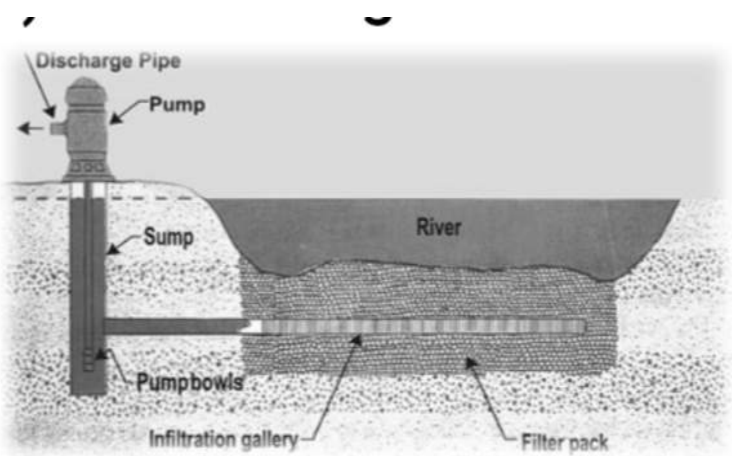
3. Surface spring

- When subsoil water forms storage due to the presence of impervious layer in the form of a valley, then the surface spring comes into existence (as shown below figure)
- A cutoff wall is constructed on the impervious layer to form a reservoir from where the water is supplied to the consumers.



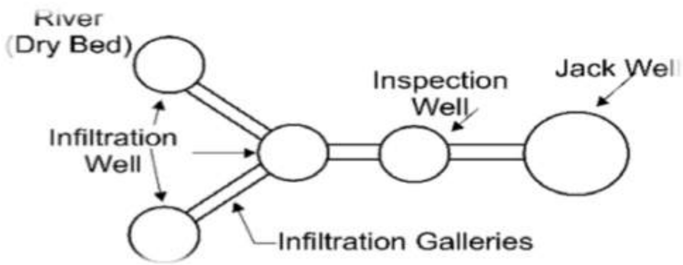
Infiltration galleries (Horizontal well):

- For tapping water from sandy river beds
- Horizontal tunnel constructed at shallow depths along the banks of river through the water bearing strata. .
- These are constructed or brick masonry with open joints
- The water percolates through these joints and gets collected in the wells
- The top of the well are covered with R.C.C slab having manhole for inspection
- Again , the water from infiltration wells gets collected in a jack well is pumped out and stored in a storage reservoir
- The quality of water is good and it requires no treatment
- The quantity of water from this source is suitable for small water supply scheme.



Infiltration wells:

- Shallow wells constructed in series along the banks of river to collect river water seeping through their bottom. The water collected in them is taken to a jack well, from where it is pumped.
- Figure shows the arrangements of wells and galleries



Wells and tube wells:

- Artificial vertical holes excavated through the earth strata for lifting ground water.
- Well may be two types-open and tube type
- The **open well** draws water from the topmost pervious layer
- The diameter varies from 1m to 3m and depth varies from 10m to 20m depending upon the nature of soil and depth of water table
- This type of wells is suitable for meeting the requirements of individual homes.
- The **tube well** draws water from the lowermost pervious layer
- The diameter varies from 40mm to 150mm and depth varies from 100m to 300m depending upon the nature of soil and suitable water bearing strata
- The tube well is constructed by sinking G.I pipes
- The deep tube well is considered as the best source of water for any water supply scheme.

<u>QUALITY AND QUANTITY OF GROUND WATER</u>

Quality: These water are free from suspended impurities and organic matter and less contaminated by bacteria.

- They contain dissolved salts, minerals, gases etc which imparts tastes, odours, hardness etc.
- These can be supplied to the public with minor treatment

Quantity: available is less than that of surface water. Availability depends on underground storage and geologic formation.

<u>Comparative study between Surface and Ground water source</u>

ITEM	SURFACE SOURCE	GROUND SOURCE
Quality	• Contaminated by Gases and dusts from atmosphere get added to the rain water • Sewage and industrial wastes get added to the water • Inorganic impurities like silt, clay, etc. get added due to erosion • Organic impurities get added in the form of vegetable washings, dead matters etc. • Algae, weed and other plant growth in still water imparting bad smells, tastes and colours	• These water are free from suspended impurities and organic matter and less contaminated by bacteria • They contain salts, minerals, gases etc which imparts tastes, odours, hardness etc.
Quantity	• Depends upon the rainfall • May be too high or may be too less	• Quantity available is less than that of surface water • Availability depends on underground storage and geological formation
Treatment required	• Surface water are generally contaminated and cannot be used without treatment	• These can be supplied to the public with minor treatment or without any treatment
Intake	• Direct pumping	• Intake by springs, infiltration galleries and wells

FACTORS GOVERNING SELECTION OF SOURCE:

- **Quantity of available water:** The quantity available must be sufficient to meet the various demands during the entire design period.
- **Quanlity of available water:** Impurities present should be as less as possible and it should be such as to remove easily and economically by normal treatment methods. The water must to be toxic, poisonous or in any other way injurious to health.
- **Distance of the source:** Source must be as near as possible. Otherwise increase the cost of the project.
- **General topography of intervening area:** The area between the source and the city should not be highly uneven. It increases the cost for conveyance, construction and maintenance.
- **Elevation of source:** Source must be lying higher than the city so as to make gravity flow possible. Otherwise pumping has to be resorted.

WATER DEMAND

Types of water demands are:

1. Domestic water demands

2. Industrial water demands

3. Institution and commercial water demand

4. Demand for public use

5. Fire demand

6. Water required compensating losses in wastes and thefts

Domestic water demand: (50% to 60%)

- Water required in residential buildings for drinking, cooking, bathing, lawn sprinkling, gardening, sanitary purpose etc.

- Minimum domestic consumption for towns and cities (High income group – HIG) with full flushing system – **200 l/h/d**
- Minimum domestic consumption for weaker section and colonies (Low income group – LIG) without full flushing – **135 l/h/d**

Domestic use of HIG:

Use	Consumption in Ipcd
Drinking	**5**
Cooking	**5**
Bathing	**75**
Washing of clothes	25
Washing of utensil	15
Washing and cleaning of houses and residences	15
Lawn watering and gardening	15
Flushing of water closets, etc.	45
Total	**200**

Domestic use of LIG

Use	Consumption in lpcd
Drinking	**5**
Cooking	**5**
Bathing	**55**
Washing of clothes	20
Washing of utensil	10
Washing and cleaning of houses and residences	10
Flushing of water closets, etc.	30
Total	**135**

Industrial water demands:

- Ordinary water demands for industries – **50 l/h/d**

Institution and Commercial water demands:

- Water requirements of institution such as hospital, hotels, restaurants, schools, colleges, railway station, offices etc.
- Average consumption – **20 l/h/d**
- It can be as high as **- 50 l/h/d**

Demand for Public use:

- Water required for public purpose such as watering public park, gardening, washing and sprinkling on roads, public fountain etc.
- Average consumption – **10l/h/d**

Fire Demand:

- Water required for extinguishing fire **– less than 1%**
- Hence it is neglected while computing total per capita demand
- Fire hydrants fitted to water mains in every 100 -150m. Generally in a fire out break – 3 jet streams are thrown from each hydrant**.** One on the burning property, one each on the adjacent property. Discharge of each stream is 1100 L/min.
- Consider a city having population 50lakh, if 6 fire break out in a day & each stands for 3 hrs. Then the total amount of water required is given as follows

  Amount of water required (Q) = No. Of fires * Discharge * Time of each fire

  Q =6 (3×1100) (3×60) = 3564000 L/day

  Amount of water required per person = 3564000/5000000 = 0.713 < 1 l/h/d

Calculation of fire Demand:

- For cities having population > 50000

  The required amount of water = 100 $\sqrt{p}$ where P = population in 1000

Fire demand is calculated by using following formula.

a. **Kuichlings formula:**

$$Q = 3182\sqrt{p}$$

b. Freeman formula:

$$Q = 1138[P/10 + 10]$$

c. National board of fire under writers formula:

c .a) For a central congested high valued city,

i) When **P ≤ 2**lakhs

$$Q = 4637\sqrt{p}\,[1-0.01\sqrt{p}]$$

ii) When **P** > 2lakhs

A provision of **54600liters / minute** may be made with an additional provision **of 9100 to 36400 liters / minutes** for a second fire

c. b) For a residential city,

i) Small or low building – **2200 liters / minute**

ii) Large or higher building **– 4500 liters / minute**

iii) High value residence, apartment – **7650 to 13500 liters / minute**

iv) Three storyed buildings **– upto 27000 liters / minute**

d. Bustons formula:

Q= $5663\sqrt{p}$

Where Q= amount of water required in litres/minute, p-population in thousands

Water required to compensating losses in waste and thefts

Losses are due to

- Leakage due to bad plumbing and damages

- Stolen water
- Other losses
- These losses should taken into account while estimating the total requirements

VARIATION ON RATE OF DEMAND

It is observed that the consumption per capita varies from season to season , month to month, day to day as well as hour to hour. The peak demand , ie the maximum consumption in an hour or in a day depends on the habits of the people ,climate conditions, the presence of industry, type of industry, and the mode or hours of supply of water by the authorities

Seasonal variations: large use of water in summer season, lesser in winter and much less in rainy season.

Daily variation: day to day variation. Water consumption will be more on Sundays and holidays.

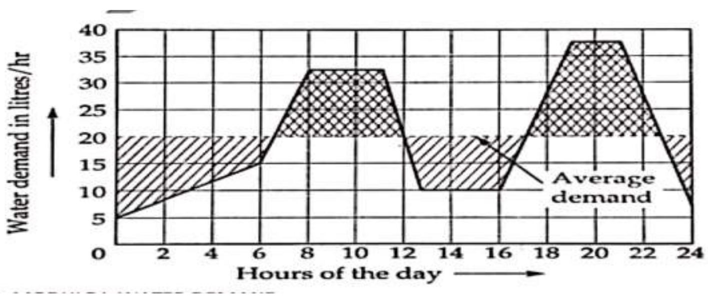
- Annual average daily demand (l/d)=total annual draft divided by 365
- Maximum daily demand= 1.8*Annual average daily demand.

Hourly variation: hour to hour variation

- Maximum hourly demand= 1.5*average hourly demand of max day
- Maximum hourly demand= 2.7*annual average hourly demand

The hourly variation is shown below

- 0 to 8 AM – less consumption
- 8 to 11 AM – high consumption
- 4 to 9 PM – high consumption



so, an adequate quantity of water must be available to meet the peak demand. To meet all the fluctuations, the supply pipes ,service reservoirs and distribution pipes must be properly proportioned. The water is supplied by pumping directly and the pumps and distribution system must be designed to meet the peak demand

Design demand for the components of water supply system

- **Source of supply :** Max.daily demand
- **Pipe mains** (from source to service reservoir): Max.daily demand
- **Filters and other units:** Twice the average daily demand
- **Pump:** Twice the average daily demand
- **Distribution system**: Total draft

Total draft is the greater of the following

- **Coincident draft:** Max.daily demand + fire demand
- **Max. hourly demand**

TOTAL QUANTITY OF WATER REQUIRED BY THE COMMUNITY

The total requirement of water by the community depends on the following factors:

1.Poplulation of the community

- Determination of population is one of the most important factors in the planning.
- If the project has to serve the community for a certain design period.
- The probable population at the end of the design period can be forecasted by using various methods.

1.Arithmetical increase method
2.Geometrical increase method
3.Incremental increase method
4.Graphical extension method
5.Graphical comparison method
6.Zoning method or master plan method
7.Ratio and correlation method

8.Logistic curve method

2. Rate of water supply per capita per day

- It is the amount of water supplied per person per day to satisfy the various demands.
- It is expressed as litres per capita per day (lpcd)
- *Per capita consumption per day in litres = total consumption in litres in year/(population*365)*
- Generally the per capita demand values ranges between 100-300lpcd
- For an average Indian town, as per I.S recommendations the per capita demand may be taken as given in table below.

Use	Demand (lcpd)
Domestic use	135
Industrial use	50
Commercial use	20
Public use	10
Waste and thefts	55
Total	270

- The above table 270 lpcd when multiplied by the population at the end of the design period gives the total annual average water requirement of the city/day
- When multiplied by 365 will give the volume of the yearly water requirement in litres.

Factors affecting per capita demand (factors affecting consumption)

1. Size of the city

- Per capita demand for big cities is large as compared to small cities.
- For big cities, more water required for maintaining clean and healthy environment.
- In big cities, industrial and commercial activities are more thus requiring more water.

2. Climatic conditions

- More water consumed at hotter and dry places, because more of bathing ,cleaning ,air cooling, gardening etc. Are involved.

3. Type of gentry and habits of people

- Water consumption depends on the economic status of the consumers.
- Upper class communities consume more water than lower class communities.

4. Industrial and commercial activities

- Water consumption will be more if the industrial and commercial activities are more.

5.Quality of water supplies

- Rate of consumption increases with quality of water.
- It the quality of water is high, people will not use other source of water.

6.Pressure in the distribution system

- Water consumption increases with pressure of water in the system.
- People living in upper storeys will use water freely.
- Loss and wastage due to leakage will be high if the pressure is high.

7. Development of sewerage facilities

- Consumption will be high for flush system than old conventional system.

8. Supply system

- Continuous system: water supplied continuously for 24 hour. generally consumption will be more.
- Intermittent system: water supplied for only peak period during morning and evening. Generally consumption will be less. but sometime the consumption in intermittent system will increases due to the following reasons:
  1. People will store water in tanks and drum for supply periods this water is thrown away if unutilized as soon as the supply is restored
  2. People have the tendency to keep the taps open during non- supply hours so as to know the arrival of water . Many times water goes on flowing unattended resulting in wastage of water.

9. Cost of water

- Water consumption decreases with increases in cost.

10. Policy of metering and method of charging

- On the basis of meter reading :consumption will be less
- 0n the basis of fixed rate: consumption will be more

3. Design period.

- A water supply scheme includes huge and costly structures which cannot be replace or increased in their capacities easily.
- In order to avoid the difficulties arising out of future expansion, the components of water supply scheme are purposely larger.
- Thus the scheme should satisfy the needs of the community for reasonable number of year to come.
- This future period or number of year for which provisions is made including the construction periods of the scheme is called design period.
- The design period should be neither be too short or too long, as to make the scheme uneconomical.
- A design period of 20 to 30 year is generally adopted
- The design period for various project components may be taken as follows:

Components	Design periods
Storage reservoir	50 years
Infiltration work	30 years
Pipe connection in plant	30 years
Raw water and clear water conveyance	30 years
Distribution system	30 years
water treatment units	15 years
Electric motors and pumps	15 years

POPULATION

- Present Population of a town can be determined by conducting an official enumeration is called census.
- Census is conducted at an interval of about 10 years.

POPULATION GROWTH

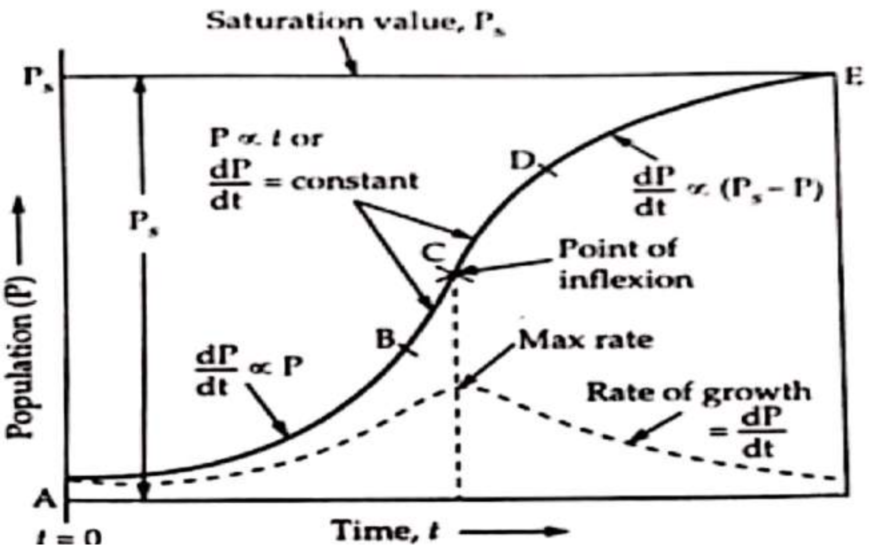
The factors affecting population growth

- Birth rate
- Dead rate
- Migration

  If these factors do not produce any extraordinary changes, the growth curve will be S-shaped and is known as logistic curve .it is also called ideal population growth

IDEAL POPULATION CURVE:

Figure shows the curve that will obtained if the population of town is platted with respected to time under normal condition.



- AB represents an increasing rate (geometric or log growth . dp/dt α P)
- BD represents arithmetic increase (dp/dt = a constant)

- No drastic changes ,only constant changes
- DE represents a decreasing rate (dp/dt α $(P-P_s)$)

FACTORS AFFECTING POPULATION GROWTH

- ✓ Social facilities: educational, medical, recreational and other social facilities
- ✓ Communication links: connection of the town with other big cities and also to the mandies of agriculture products
- ✓ Tourism: tourist facilities, religious places or historical products
- ✓ Community life: living habits, social customs and general education in the community
- ✓ Unforeseen factors: earthquakes ,floods , epidemics ,frequent famines etc may affect growth of population

POPULATION FORCASTING.

- The data about the present population of a city under consideration can be obtained from the senses records of the municipality or civic body
- Once decided the design period ,the population to be served at the end of the period should be forecasted to calculate the water requirements.
- The population at a future date is determined from present population of the previous years.
- The following are some methods by which future population is forecasted.
    1. Arithmetical increase method
    2. Geometrical increase method
    3. Incremental increase method
    4. Decreasing rate of growth method
    5. Graphical extension method
    6. Graphical comparison method
    7. Zoning method or master plan method
    8. Ratio and correlation method
    9. Logistic curve method

1. Arithmetic increases method:

- Population increase at constant rate
- Applicable to old and large cities with no industrial growth and reached a saturation or maximum development

$P_n=P_0+n\bar{x}$

P_n=population after n decades

P_0=population at present

n=number of decades between now and future

$\bar{x}$ = average of population increase

Q1. The population of 5 decades from 1930 to 1970 is given below. Find out the population after one, two and three decades beyond the last known decade,by using arithmetic increase method

Year	1930	1940	1950	1960	1970
population	25000	28000	34000	42000	47000

Year	Population	Increase in Population
1930	25000	-
1940	28000	3000
1950	34000	6000
1960	42000	8000
1970	47000	5000
Total		22000
Average increase per decade ($\bar{x}$)		$\bar{x} = \frac{22000}{4} = 5500$

Future population is computed by

$Pn = P_0 + n\bar{x}$

Population after 1 decade beyond 1970

$P_{1980} = P_{1970} + 1\bar{x} = 47000 + 1 \times 5500 =$ **52500**

Population after 2 decade beyond 1970

$P_{1990} = P_{1970} + 2\bar{x} = 47000 + 2 \times 5500 =$ **58000**

Population after 3 decade beyond 1970

$P_{2000} = P_{1970} + 3\bar{x} = 47000 + 3 \times 5500 =$ **63500**

Example: 2 Predict the population for the year 2021, 2031, and 2041 from the following population data.

Year	1961	1971	1981	1991	2001	2011
Population	8,58,550	10,15,685	12,01,593	16,91,582	20,77,840	25,85,895

Solution:

Year	Population	Increment
1961	858550	
1971	1015685	157135
1981	1201593	185908
1991	1691582	489989
2001	2077840	386258
2011	2585895	508055
Total		1727345

Average increment $\bar{x} = \frac{1727345}{5} = 345469$

Population forecast for year 2021 is,

$P_{2021} = 2585895 + 345469 \times 1 = 2931364$

Similarly, $P_{2031} = 2585895 + 345469 \times 2 = 3276833$

$P_{2041} = 2585895 + 345469 \times 3 = 3622302$

2. Geometric increase method or uniform increase method

- Percentage increase in population from decades to decade is constant.
- It gives good results for young and rapidly growing city.
- The population at the end of n[th] decade ' P_n'=$P_0(1+r/100)^n$

r = growth rate in %

r can be computes as follows

$$r = \sqrt[n]{\frac{P_2}{P_1}} - 1 \quad \text{OR} \quad \sqrt[n]{r_1\ x\ r_2\ x \ldots\ldots x\, r_n}$$

Where, P_1– initial known population, P_2– Final known population, n- no. of decades

Q3: The population of 5 decades from 1930 to 1970 is given below. Find out the population after one, two and three decades beyond the last known decades ,by using geometric increase method

Year	1930	1940	1950	1960	1970
population	25000	28000	34000	42000	47000

Solution:

Year	Population	Increase in Population	Percentage increase in population
1930	25000	-	
1940	28000	3000	(3000/25000)X100 = 12%
1950	34000	6000	(6000/28000)X100 = 21.4%
1960	42000	8000	(8000/34000)X100 = 23.5%
1970	47000	5000	(5000/42000)X100 = 11.9%

Growth rate is given by

$$r = \sqrt[n]{r_1 \ x \ r_2 \ x \ \ldots \ldots . x \ r_n}$$

$$r = \sqrt[4]{12 \ x \ 21.4 \ x \ 23.5 \ x \ 11.9} = 16.37\%$$

Future population by Geometric method is given by

$$P_n = P_0(1 + \frac{r}{100})^n$$

Population after 1 decade beyond 1970

$$P_{1980} = P_{1970}(1 + \frac{16.37}{100})^1$$

$$= 47000(1 + \frac{16.37}{100})^1$$

= 54694

Population after 2 decade beyond 1970

$$P_{1990} = P_{1970}(1 + \frac{16.37}{100})^2$$

$$= 47000(1 + \frac{16.37}{100})^2$$

= 63647

Population after 3 decade beyond 1970

$$P_{2000} = P_{1970}(1 + \frac{16.37}{100})^3$$

$$= 47000(1 + \frac{16.37}{100})^3:$$

= 74066

Q4: Compute the population of the year 2000 and 2006 for a city whose population in the year 1930 was 25000 and in the year 1970 was 47000. Make use of geometric increase method

Solution: Growth rate can be computed by

$$r = \sqrt[n]{\frac{P_2}{P_1}} - 1$$

$$r = \sqrt[4]{\frac{47000}{25000}} - 1 = 17.095\%$$

Future population by geometric method is given by

$$P_n = P_0(1 + \frac{r}{100})^n$$

Population of 2000 (n = 3)

$P_{2000} = P_{1970}(1+17.095/100)^3$

$P_{2000} = 47000(1+17.095/100)^3 = 75459$

Population of 2006 (n = 3.6)

$P_{2006} = P_{1970}(1+17.095/100)^{3.6}$

$P_{2006} = 47000(1+17.095/100)^{3.6} = 82954$

<u>3.Increamental increase method or varying increment method</u>

- It is the modification of arithmetical increase method
- Give result between arithmetic method and geometric method

- It is applicable to any city , whether old or new
- While adopting this method the increase in increment is considered for calculating future population.

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}.\bar{y}$$

Pn- Population after n decades

$\bar{x}$-Average increase of population

$\bar{y}$-Average of incremental increase

Q5. The population of 5 decades from 1930 to 1970 is given below. Find out the population after one, two and three decades beyond the last known decades,by using increamental increase method

Year	1930	1940	1950	1960	1970
population	25000	28000	34000	42000	47000

Year	**Population**	**Increase in Population**	**Incremental increase**
1930	25000	-	-
1940	28000	3000	-
1950	34000	6000	+3000
1960	42000	8000	+2000
1970	47000	5000	-3000
Total		22000	+2000
Avg Increase Per Decade		(22000/4)= **5500 =** $\boldsymbol{\bar{x}}$	(2000/3) = **+667=** $\boldsymbol{\bar{y}}$

Future population by incremental increase method is given by

$P_n=P_0+n\bar{x}+\frac{n(n+1)}{2} * \bar{y}$

Population of 1980,

P_{1980}=P_{1970}+$1\overline{x}$+$\frac{1(1+1)}{2}*\overline{y}$

P_{1980}= 47000+1*5500+667=53167

Population of 1990,

P_{1990}=P_{1970}+$2\overline{x}$+$\frac{2(2+1)}{2}*\overline{y}$

P_{1990}= 47000+2*5500+$\frac{2(2+1)}{2}$*667=60001

Population of 2000,

P_{2000}=P_{1970}+$3\overline{x}$+$\frac{3(3+1)}{2}*\overline{y}$

P_{2000}= 47000+3*5500+$\frac{3(3+1)}{2}$*667=67502

Q5: In a town it has been decided to provide 200 l per head per day in the 21st century. Estimate the water requirements of this town in the year AD 2000 by projecting the population by incremental increase method

Year	Population
1940	23798624
1950	46978325
1960	54786437
1970	63467823
1980	69077421

Year	Population	Increase in population	Incremental increase
1940	23798624		
1950	46978325	2319701	
1960	54786437	7808112	-15371589
1970	63467823	8681386	+873274

1980	69077421	5609598	-3071788
Total		45278797	-17570103
Average		**(45278797/4)** **=11319699 =** $\bar{x}$	**(-17570103/3)** **= -5856701 =** $\bar{y}$

Expected population at the end of year 2000 (after 2 decades from 1980)

$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} * \bar{y}$

$P_{2000} = P_{1980} + 2\bar{x} + \frac{2(2+1)}{2} * \bar{y}$

$P_{2000} = 5609598 + 2*11319699 + \frac{2(2+1)}{2} *(-5856701) = 74146716$

So the water required = 74146716*200=14829343200

4. Decreasing rate of growth method

- Applicable where the rate of growth shows a downward trend

  $$P_n = P_0\left[1+\frac{r_0 - D}{100}\right]\left[1+\frac{r_0 - 2D}{100}\right] \ldots\ldots[1+\frac{r_0 - nD}{100}]$$

  r_0=percentage increase in population of last known decade

  D=average decrease in the percentage increases

Q7. The population of 5 decades from 1930 to 1970 is given below. Find out the population afterone, two and three decades beyond the last known decades ,by decrease rate of growth method

Year	1930	1940	1950	1960	1970
population	25000	28000	34000	42000	47000

Year	**Population**	**Increase in Population**	**Percentage increase in population**	**Decrease in the percentage increase**
1930	25000	-	-	

1940	28000	3000	(3000/25000)x 100 = 12%	
1950	34000	6000	(6000/28000)x 100 = 21.4%	12 – 21.4 = - 9.4 %
1960	42000	8000	(8000/34000)x 100 = 23.5%	21.4 – 23.5 = - 2.1 %
1970	47000	5000	(5000/42000)x 100 = 11.9%	23.5 – 11.9 = + 11.6 %
Total		22000		-9.4 – 2.1 + 11.6 = 0.1 %
Average per decade				**=0 .03% decrease**

Future population by decreasing rate

$$P_n = P_0\left[1+\frac{r_0 - D}{100}\right]\left[1+\frac{r_0 - 2D}{100}\right] \ldots \ldots [1+\frac{r_0 - nD}{100}]$$

Expected population at 1980,

P_{1980}=$P_{1970}[1 + \frac{11.9-0.03}{100}]$

P_{1980}= $47000[1 + \frac{11.9-0.03}{100}]$=52570

Expected population at 1990,

P_{1990}=$P_{1970}[1 + \frac{11.9-1*0.03}{100}][1 + \frac{11.9-2*0.03}{100}]$

P_{1990}= $47000[1 + \frac{11.9-1*0.03}{100}][1 + \frac{11.9-2*0.03}{100}]$ =58800

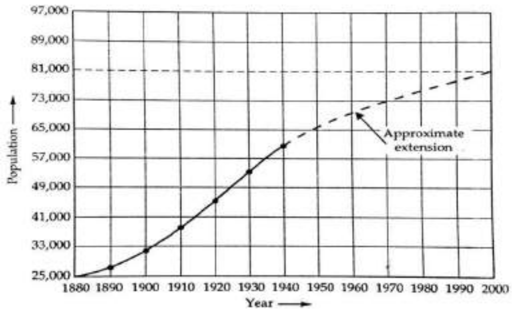
Expected population at 2000,

P_{1990}=$P_{1970}[1 + \frac{11.9-1*0.03}{100}][1 + \frac{11.9-2*0.03}{100}]\ 1 + [\frac{11.9-3*0.03}{100}]$

P_{1990}=$47000[1 + \frac{11.9-1*0.03}{100}][1 + \frac{11.9-2*0.03}{100}]\ 1 + [\frac{11.9-3*0.03}{100}]$ =65750

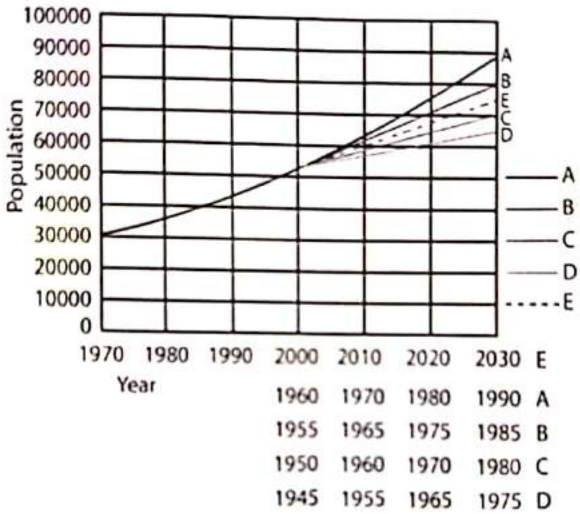
5.Simple graphical method or graphical extension method

- A graph is plotted between time and population. The curve is then smoothly extended up to the desired year.
- This extension should be done carefully and it requires proper experience and judgement.
- This gives approximate results. It is unsafe to use this method.



6. <u>Comparative graphical method or graphical comparison method</u>

- Based on the assumption that the city under consideration many develop same as the selected similar cities developed in the past.
- Population with time is plotted for the city and is extended based on the curve of selected city.
- The advantage of this method is that the future population can be predicted from the present population even in the absence of some of the past census report
- The use of this method is explained by a suitable example is given below.



- The population of city E under consideration is plotted up to 2000 at which the population is 50000
- The city A having similar conditions, reached the population of 50000 in 1960 and its curve is plotted from 1960 onwards.

- Similar curve are plotted for cities B,C and D which reached the population of 53000 in 1995,1950,1945 respectively
- The curve of city E can be then continued (shown dotted line).

7. Master plan method or zoning method

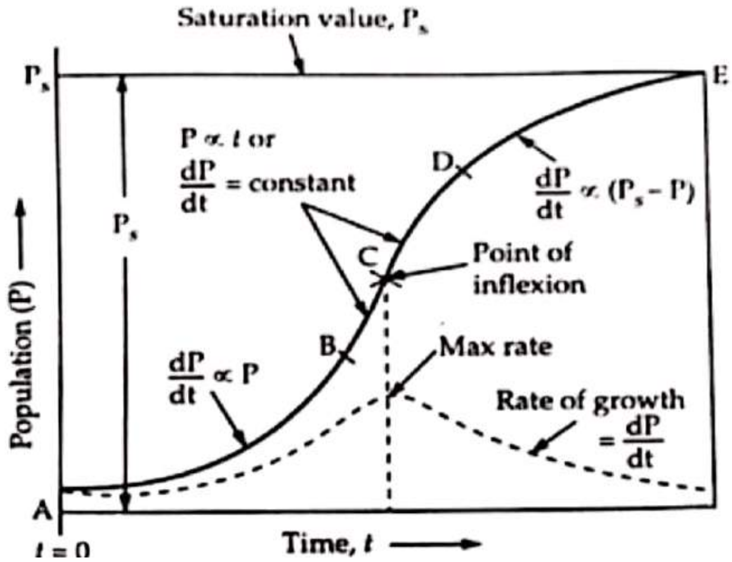
- The big and metropolitan cities are generally not developed in hazard manner, but are planned and regulated by local bodies according to master plan.
- Master plan prepared for next 25 to 30 years for the city
- According to the master plan the city is divided into various zones.
- The population densities in each zone is fixed in the masterplan
- From this population density total water demand and wastewater generation for that zone can be worked out.

8. Ratio and correlation method or apportionment method

- The ratio of local population to national population are worked out in the previous two or more decades.
- A graph is plotted between time and these ratios and extended up to the desired year.
- Extrapolate the ratio corresponding to the future period and it is then multiplied by the expected population at the future period to get the local population
- Applicable to area where growth is parallel to the natural growth.

8. Logistic curve method

- This method is used when the growth rate of population due to births , deaths and migrations take place under normal condition and it is not subjected to any extraordinary changes like war, earthquake etc.
- It there is no extra ordinary changes in population the growth curve will be S- shape and is known as logistic curve or ideal population growth curve.
- Figure shows the curve that will obtained if the population of town is platted with respected to time under normal condition



- AB represents an increasing rate (geometric or log growth . dp/dt α P)
- BD represents arithmetic increase (dp/dt = a constant)
- No drastic changes ,only constant changes
- DE represents a decreasing rate (dp/dt α (P-P_s))

$$P = \frac{P_s}{1 + m.loge^{-1}(nt)}$$

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{(P_0P_2 - P_1^2)}$$

$$m = \frac{P_s - P_0}{P_0}$$

$$n = \frac{1}{t_1} log_e[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}]$$

$$n = \frac{2.3}{t1} \log 10[\frac{P0(PS-P1)}{P1(PS-P0)}]$$

where,

P0-population at t0 = 0

P1-Population at t1

P2- Population at t2

Q8.In two periods of each of 20 years, a city has grown from 30000 to 170000 and then to 300000. Determine (a) saturation population (b) equation of the logistic curve (c) expected population after the next 20 years.

Solution:

P_0-30000 t_0-0

P_1-170000 t_1-20years

P_2- 300000 t_2-40years

Saturation Population is given by

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{(P_0P_2 - P_1^2)}$$

$$P_s = \frac{2X30000\ X\ 170000\ X\ 300000 - 170000^2(30000 + 300000}{(30000\ X\ 300000 - 170000^2)}$$

$$P_s = 326000$$

Equation of logistic curve

$$P = \frac{P_s}{1 + m.\,loge^{-1}(nt)}$$

$$m = \frac{P_s - P_0}{P_0}$$

$$m = \frac{326000 - 30000}{30000} = 9.87$$

$$n = \frac{1}{t_1} log_e[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}]$$

$$n = \frac{1}{20} log_e \left[\frac{30000(326000 - 170000)}{170000(326000 - 30000)}\right]$$

= -0.119

Now the equation will become

$$P = \frac{326000}{1 + 9.87 * loge \quad (-0.119t)}$$

Population after 60 years (t=60 years)

$$P = \frac{326000}{1 + 9.87 * loge - \quad (-0.119 * 60)} = 323000$$

Q. The following is the population data of a city available from past census records. Determine the population of the city in 2021 by a) arithmetical increase method b) geometrical increase method c) incremental increase method.

Year.	1941	1951	1961	1971	1981	1991	2001
population	12500	17000	27000	42000	58000	68000	74000

Year	Population	population increase	percentage increase in population	incremental increase.
1941	12500	--		-
1951	17000	4500.	36%	-
1961	27000	10000	58.82%.	+5500
1971	42000	15000	55.56%.	+5000
1981	58000	16000	38.10%.	+1000
1991	68000	10000	17.24%.	-6000
2001	74000	6000	8.82%	-4000
Total		61500	214.54	+1500
Average		$\bar{x}$ = 10250		$\bar{y}$ = 300

In the above table, percentage increase for the first decade (1941 to 1951)

$$= \frac{17000 - 12500}{12500} \times 100 = \frac{4500}{12500} \times 100 = 36\%$$

Similarly, % increment for other decades has been calculated.

Where P_0 = population in 2001 = 74000.

a) Arithmetical increase method.

n = number of decades.

$$P_n = P_0 + n\bar{x}$$

$$\frac{2021-2001}{10} = 2$$

$$P_{2021} = 74000 + 2 \times 10250$$

$$= \underline{\underline{94500}}.$$

b) Geometrical increase method.

$$P_n = P_0 \left(1 + \frac{r}{100}\right)^n$$

$$r = \sqrt[n]{r_1 \times r_2 \times r_3 \times r_4 \times r_5 \times r_6}$$

$$= \sqrt[6]{36 \times 58.82 \times 55.56 \times 35.10 \times 17.24 \times 8.82}$$

$$= \underline{\underline{29.66}} \approx \underline{\underline{30}}$$

$$P_{2021} = P_0 \left(1 + \frac{r}{100}\right)^n$$

$$= 74000 \times \left[1 + \frac{30}{100}\right]^2$$

$$= \underline{\underline{1,25,060}}.$$

c) Incremental increase method.

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2} \times \bar{y}$$

$$P_{2001} = 74000 + 2 \times 10250 + \frac{2(2+1)}{2} \times 300$$

$$= \underline{\underline{95,400}}.$$

Q.

Q. The population of a city in three consecutive years i.e 1991, 2001, & 2011 is 80,000 ; 250,000 & 480000 respectively. Determine

a) The saturation population

b) The equation of logistic curve.

c) The expected population in 2021.

Solution :-

$P_0 = 80,000 \quad t_0 = 0$

$P_1 = 250,000 \quad t_1 = 10 \text{ years}$

$P_2 = 480,000 \quad t_2 = 20 \text{ years}$

The saturation population can be calculated by

$$P_s = \frac{2 P_0 P_1 P_2 - P_1^2 (P_0 + P_2)}{P_0 P_2 - P_1^2}$$

$$P_s = \frac{2 \times 80000 \times 250000 \times 480000 - 250000^2 \times (80000 + 480000)}{80000 \times 480000 - 250000^2}$$

$$= 656,602$$

where $m = \frac{P_s - P_0}{P_0} = \frac{656602 - 80000}{80000} = 7.195$

$$n = \frac{2.3}{t_1} \log_{10} \left[\frac{P_0 (P_s - P_1)}{P_1 (P_s - P_0)} \right]$$

$$n = \frac{2.3}{10} \log_{10} \left[\frac{80000 (655602 - 250000)}{250000 (655602 - 80000)} \right]$$

$$n = -0.1488$$

Hence logistic curve equation is

$$P = \frac{P_s}{1 + m \log_e^{-1}(n \times t)}$$

$$= \frac{655602}{1 + 7.195 \log_e^{-1}(-0.1488 \times t)}$$

Since $t_1 = 2021 - 1991 = 30$ years.

Population in 2021 $= \frac{655602}{1 + 7.195 \log_e^{-1}(-0.1488 \times 30)}$

$$= \frac{655602}{1 + 7.195 \times 0.0117}$$

$$= \underline{\underline{605436}}.$$

MODULE- II

Types of intakes-Conveyors, Pumps and Location of pumping station-Quality of water - Drinking water standards - Physical, Chemical and Biological analysis

INTAKE STRUCTURES:

These are structure placed in surface water source to permit the withdrawal of water from this source, and discharge it into the intake conduits to the treatment plant.
These structure are masonry or concrete structures and provides relatively clean water ,free from pollution, sand and objectionable floating material.

Location of Intake:

- It should be near the treatment plant so that the conveyance cost is less
- It must be located in the purer zone of the source
- It should not be at the point of disposal
- It should not be near the navigation channel
- It should permit greater withdrawal even in future and can draw water even during driest period
- It should be easily accessible during flood
- In meandering river, weir or barrage should be provided as there will be scarcity of water
- In meandering river it is better to construct intake at the concave bank than in the convex bank as water will be available on concave side

Type of Intake:

1. Simple submerged intake
2. Intake tower
3. River intake structures
4. Canal intakes
5. Intakes for sluice ways of dams

1) SIMPLE SUBMERGED INTAKE:

- Consist of a simple concrete block or a rock filled timber crib supporting the withdrawal pipe. The withdrawal pipe is taken up to the sump well from where the water is lifted by pumps
- Screen is provided to prevent the entry of debris
- Withdraw pipe is kept at 2 to 2.5 m above the bottom of lake to avoid entry of silts and sediments
- Submerged intakes are cheap and do not obstruct navigation
- Widely used for small water supply projects from streams and lakes
- Not used for bigger projects
- They are not easily accessible for cleaning, repairing etc.

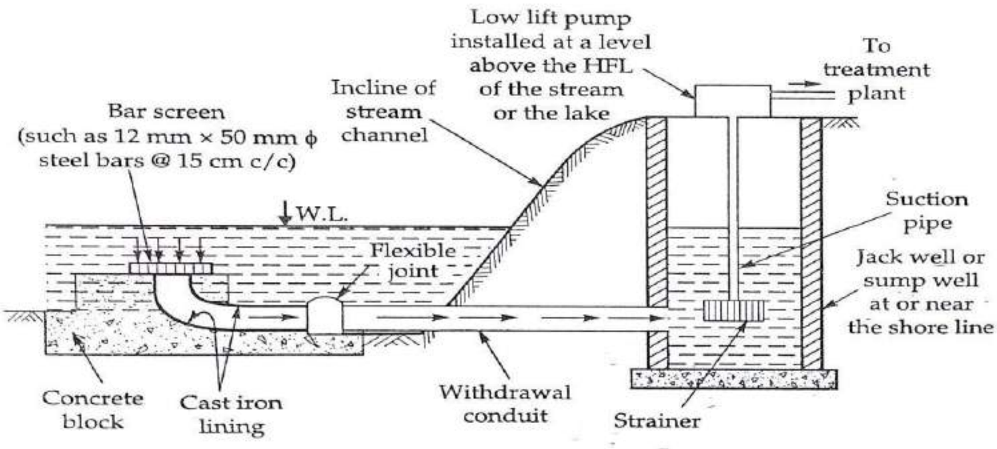


Figure 1: Submerged Intake – Simple Concrete Block

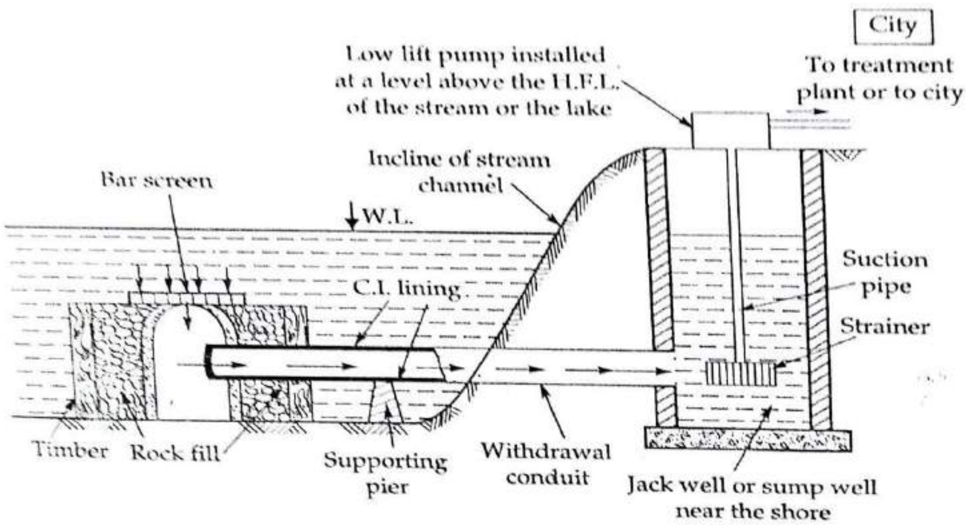


Figure 2: Submerged Intake – Rock Filled Timber Crib

2.INTAKE TOWER:

- Used on large projects on rivers or reservoirs where there are large fluctuations of water level
- Basic -Gate controlled ports are provided in these concrete towers which help in regulating the flow of water and permit water to the withdrawal conduits

Type of intake tower:

a) Wet intake tower: Consist of concrete circular shell and has a vertical inside shaft. Water enter into the shell through open ports and entry of water into the shaft is controlled by gate controlled ports and water then leads to the withdrawal conduits

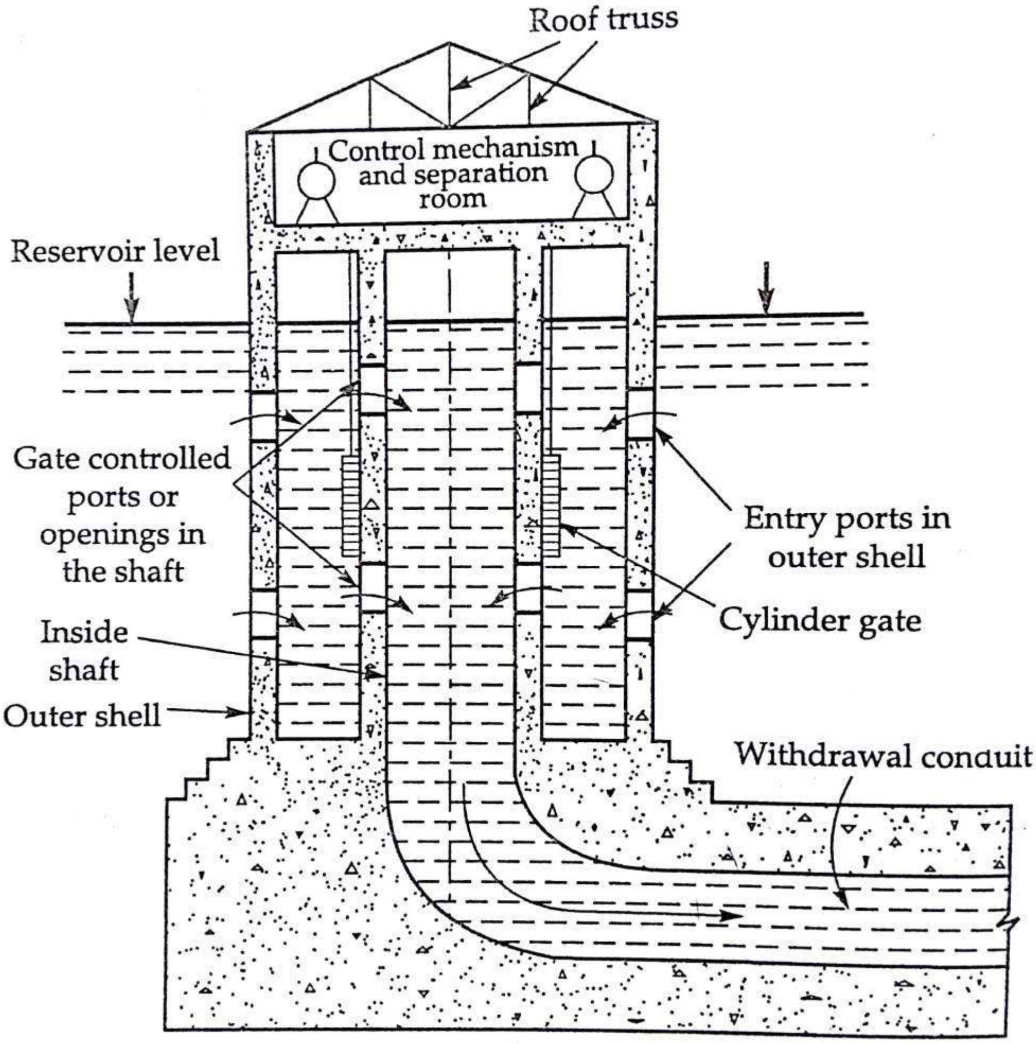


Figure 3: Wet Intake Tower

b) Dry intake tower: Consist of a circular shaft with gate controlled ports which regulate the flow of water. A dry intake tower will have no water if the gats are closed whereas in wet tower will be full of water even if the gates are closed.

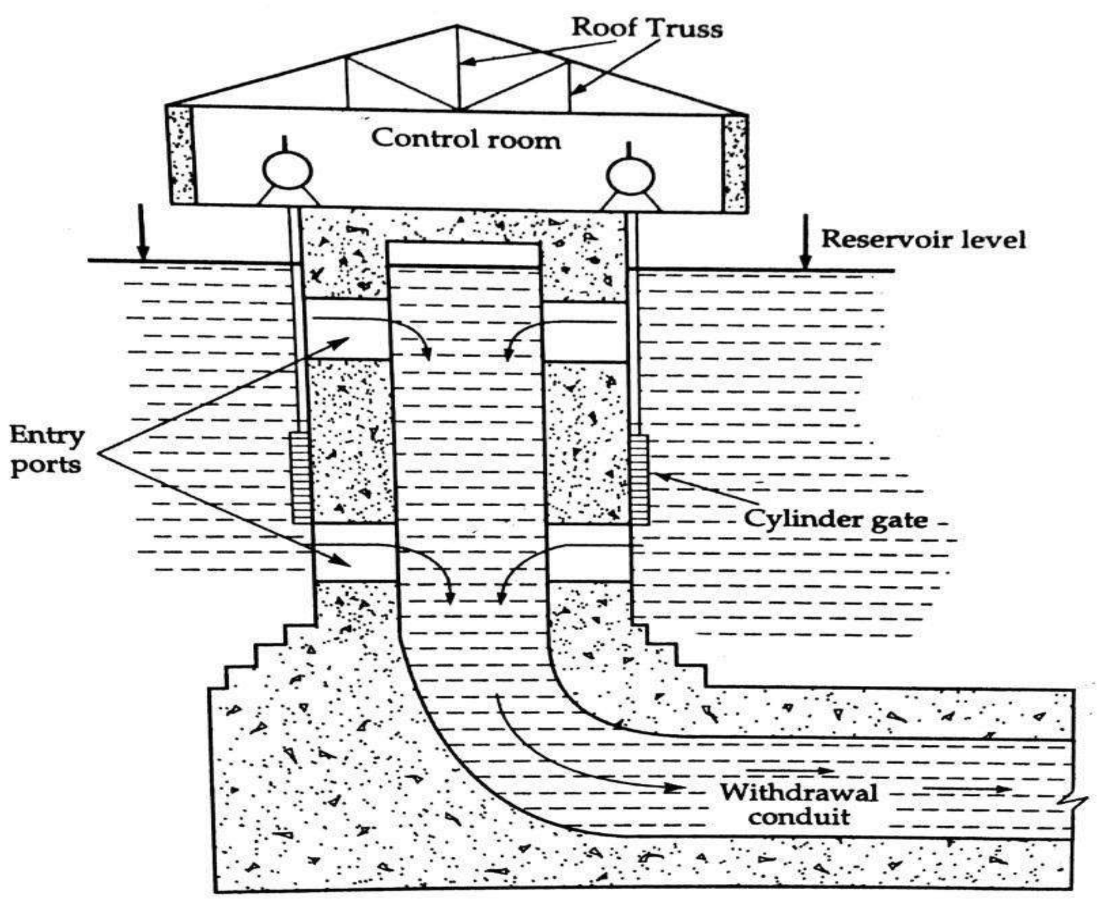


Figure 4: Dry Intake Tower

3) RIVER INTAKE STRUCTURES

- ✓ **Twin well type:** It consists of an inlet well, inlet pipe and jack well. The inlet well located in the river bed, collect water through a bar screen. Inlet pipe withdraw water from inlet well into the jack well. The jack well store the water from where water is lifted bypumps
- ✓ **Single well type:** Consist of a single jack well provided with direct entry ports from where water is then lifted by pumps
- ✓ Bar screen made of 20 mm dia vertical bars with 30 to 50mm spacing
- ✓ Upper layer of screen meet the requirement of high flood level, middle layer meet the normal flood level and lower layer meet the low water level
- ✓ Flow velocity through bar screen is limited to 15 to 20 cm/sec
- ✓ Inlet well sunk into the river bed by about 3 m

- ✓ Provide a free board of about 2 m
- ✓ Flow velocity through inlet pipe is limited to 1.2 m/sec and its diameter should be greater than 45 cm
- ✓ Lay the inlet pipe by about 1 in 200 gradient
- ✓ Diameter of jack well is kept about 4 to 5 m

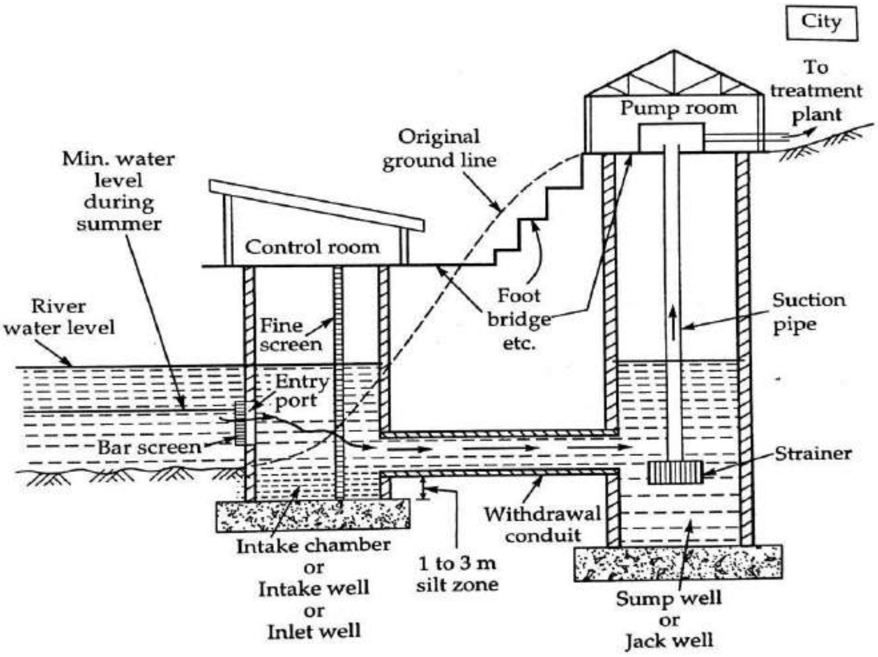


Figure 5: Twin Well Type River Intake

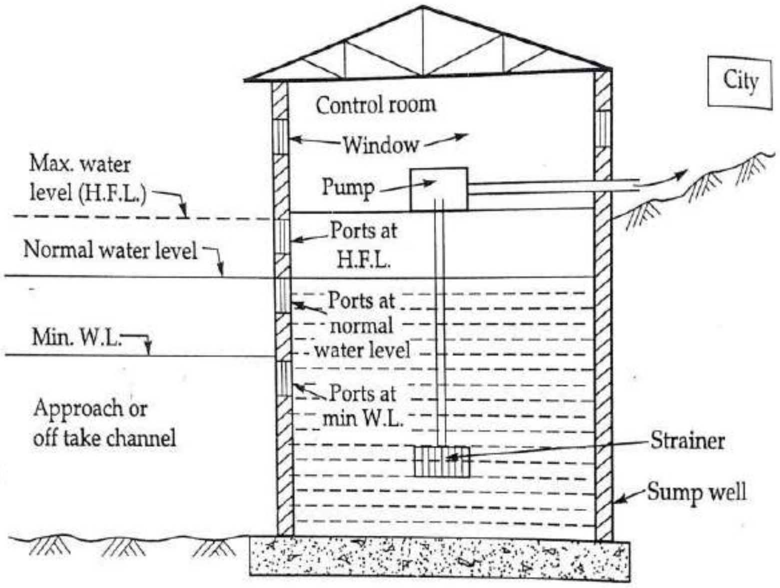


Figure 6: Single Well Type River Intake

4).**CANAL INTAKES**

- ✓ Consist of an intake well with a coarse screen for the entry of water into the well. A bell mouth inlet pipe with a fine screen is provided inside the well through which water flows into sump well.
- ✓ Top of coarse screen is provided at minimum water level and bottom is about 0.15m above canal
- ✓ The flow velocity through the outlet conduit is kept at 1.5 m/sec
- ✓ Flow velocity through the coarse screen is kept as low as 0.15 m/sec
- ✓ Flow velocity through the bell mouth inlet is limited to 0.3 m/sec

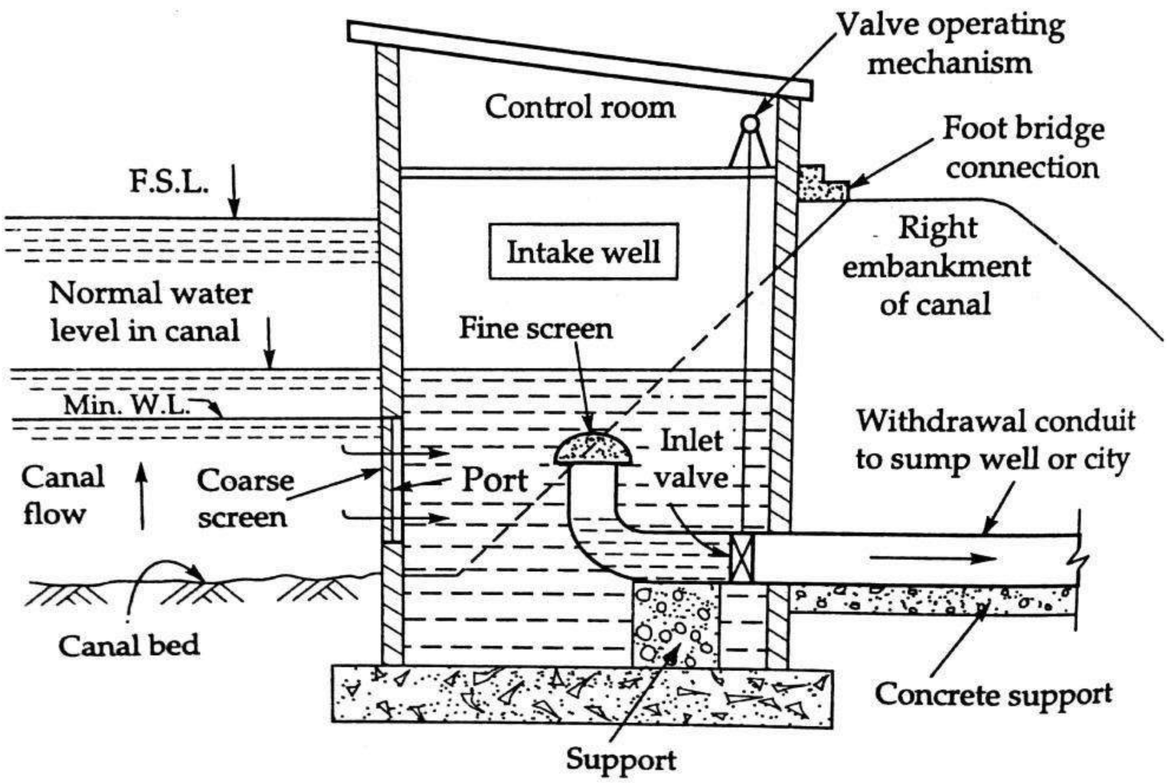


Figure 3.7: Canal Intake Well

5) INTAKES FOR SLUICE WAYS OF DAMS

- ✓ Intake conduits are installed at different levels and let the water enter to a common conduits which convey the water to the sluiceway tunnel
- ✓ A valve tower is constructed to control the flow in the different inlet conduits

✓ For Earthen dam: intake is located near the upstream or provided inside the dam

✓ For masonry or gravity dam: intake is provided inside the dam

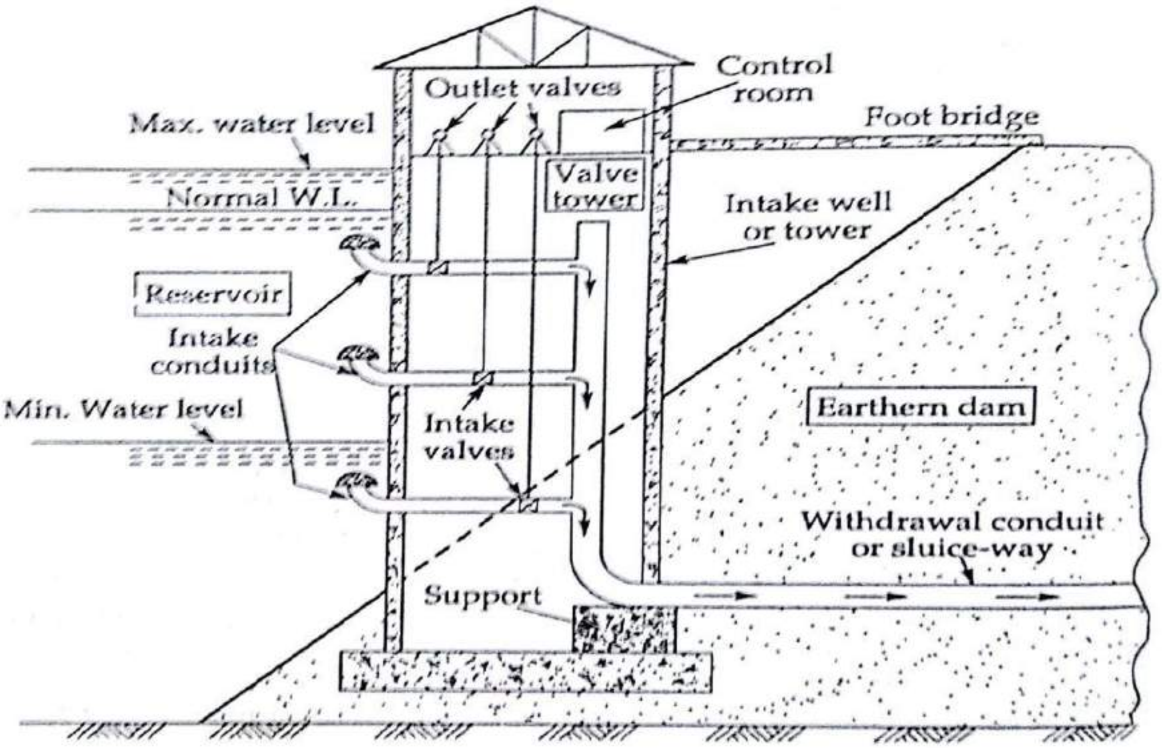


Figure 8: Intake at the Upstream Toe of Earthen Dam

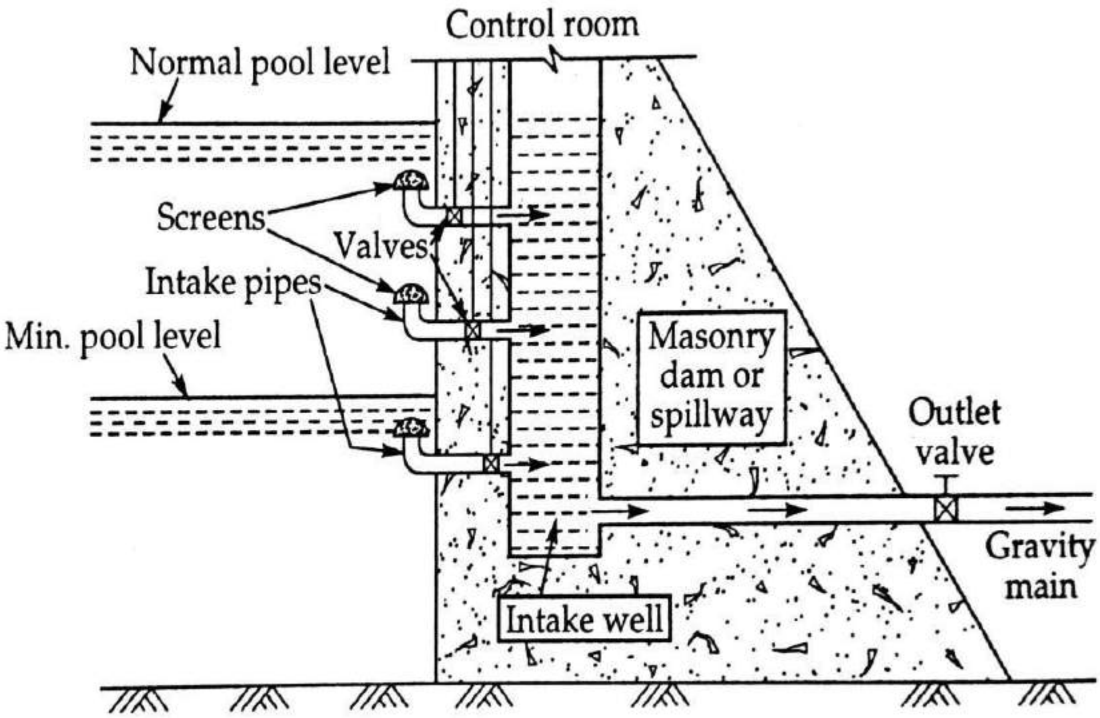


Figure 3.9: Intake for Concrete Gravity Dam

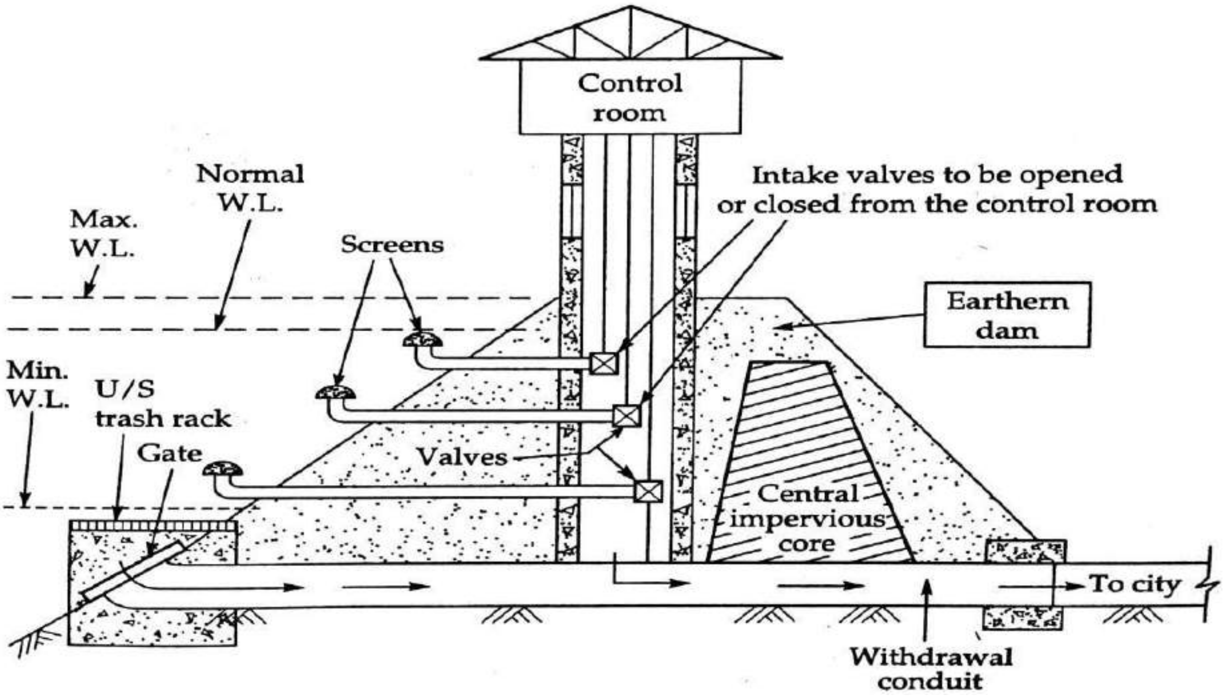


Figure 10: Intake within an Earthen Dam

PUMPING STATION: CONDUITS:

- ✓ Water collected is conveyed to the city by means of conduits

Types of conduits

- ❖ Gravity conduits
- ❖ Pressure conduits.

Gravity conduits:

- ✓ Water flows under the action of gravity
- ✓ Hydraulic gradient line coincide with the water surface and will be parallel to the bed of conduits
- ✓ Water flow at atmospheric pressure, so pressure term in Bernoulli's equation
- ✓ Gravity conduits have to follow the gradual slope of the hydraulic gradient line and cannot follow the natural slope
- ✓ Gravity conduits cannot go up and down hills and valleys as desired by the existing topography of the area

- ✓ They may be carrying in zig-zag way which will increase its length Type of Intake:

Gravity conduits can be in the form of:

Canal: Open channel constructed by cutting high ground and constructing banks on low ground. They may be lined or unlined. As it affect the quality of water, they are not used for water supplies but generally used for irrigation

Flumes: Open channel supported over the ground. Convey water across valleys, depressions and over other obstructions. They may be made of masonry, RCC or metal and usually circular or rectangular in section

Aqueducts: Closed rectangular or circular or horse shoe sections built of masonry or RCC. They are laid with a gradual slope and with ½ or ¾ full

- ✓ **Rectangular sections**: Hydraulically inefficient and require more material for construction but stable to support on ground so widely used
- ✓ **Circular sections**: most efficient, less construction cost but cannot be easily supported on ground so seldom used
- ✓ **Horse shoe sections**: Compromise between circular and rectangular section but construction is more difficult

<u>Pressure conduits:</u>

- ✓ Closed conduits such as no air can enter into them. Water flows under pressure above atmospheric pressure.
- ✓ Hydraulic gradient line is obtained by joining water surface elevation at various positions. The bed of pressure conduits is independent of hydraulic gradient line
- ✓ Pressure conduits can follow natural slopes and freely go up and down and require less length of conduits
- ✓ Pressure conduits are generally circular for hydraulic and structural reasons
- ✓ Water flowing through pressure conduits are not exposed anywhere, hence no chance of getting polluted. Hence they are widely used for water supplies

Pressure conduits may in the form of:

- Closed pipes
- Closed aqueducts
- Pressure tunnels

PUMPS

In a water supply system, pump is required for:

- To lift the water at the source
- To lift the water at the treatment plant
- To lift the water after the treatment so as to force into distribution system

Type of pump:

<u>Roto-dynamic pump</u>: Impeller rotates thus imparting energy to the water

- ✓ Centrifugal pump
- ✓ Axial flow pump

<u>Displacement pump</u>: Mechanically induced vaccum draw water and it is then mechanically forced out

- ✓ Reciprocating pump
- ✓ Rotary type pump

Factors affecting selection of pump:

- Capacity of pump
- Importance of water supply scheme
- Initial cost of pumping arrangement
- Maintenance cost
- Space requirement for locating pump
- Number of units required
- Total lift of water required
- Quantity of water to be pumped

Location of pumping station:

- Location depends upon the place from where it is to receive water and the place where it is to supply water

Selection of pumping station:

- Site should be away from all the source of contamination and pollution
- Site should be above the highest flood level
- Its future expansion should be possible
- Possibilities of fire hazard should be considered
- Proximity to the power source
- It should be placed in a neat and clean place

 It should have sufficient space between stations for their operation, repairs,

QUALITY OF WATER:

INTRODUCTION:

Pure water (H_2O) is a chemical compound containing two hydrogen atom and one oxygen atom. However pure water can never be available in nature. At the instant of formation, it contains no impurities. But as it passes through atmosphere, it may dissolve impurities. When it reaches the earth's surface, various physical, chemical and bacterial impurities are introduced.

Certain minerals such as iron, calcium, magnesium, fluorine etc. in small amount is useful and good for health. But in large amount it is unfit for use. Some toxic elements arsenic, barium, cadmium, chromium, cyanide, lead, copper etc. are harmful to the health. Some bacteria are also harmful which cause cholera, typhoid etc.

To ensure safety, the water should be thoroughly check, analyzed and treated to safe and permissible limits before applying to the public.

- **Pure water**: it is a chemical compound H_2O
- **Potable water**: Water which is fit for drinking
- **Palatable water**: water which is aesthetically looking good
- **Wholesome water**: Chemically may not be pure, but doesn't contain anything harmful to human being
- **Polluted water**: It contains undesirable substance which makes it unfit for drinking and domestic use
- **Contaminated water**: Contains pathogenic bacteria and unfit for drinking
- **Mineral water**: contains useful minerals such as iron, calcium, magnesium in required proportion

CHARACTERISTICS OF WATER:

✓ **Physical characteristics**
✓ **Chemical characteristics**
✓ **Biological characteristics**

PHYSICAL CHARACTERISTICS:

This includes:

- Turbidity
- Colour
- Taste or odour
- Temperature
- Specific conductivity

TURBIDITY

- Water appears muddy or cloudy or turbid due to the presence of suspended matter such as clay, silt or some other finely divided organic and inorganic matter
- Turbidity is also due to presence of bacteria, algae, protozoa, fungi
- It is also defined as the measure of resistance to the passage of light through the water
- Turbidity should be removed due to aesthetic and psychological reasons
- Turbidity is expressed in ppm or mg/l
- Standard unit is that which is produced by 1 mg of finely divided silica in 1 liter of water. It is measured on silica scale
- Permissible limit for potable water : 5 to 10 pp
- Turbidity is measured by using Turbidity rod or Turbidimeter

Turbidity rod

- Used to measure turbidity in the field
- Consist of graduated aluminium rod which directly gives the turbidity in silica units (mg/l). A graduated tape at the upper end for lowering the rod into the water. There is a mark for eye position on the gradated tape. A platinum needle provided at the bottom

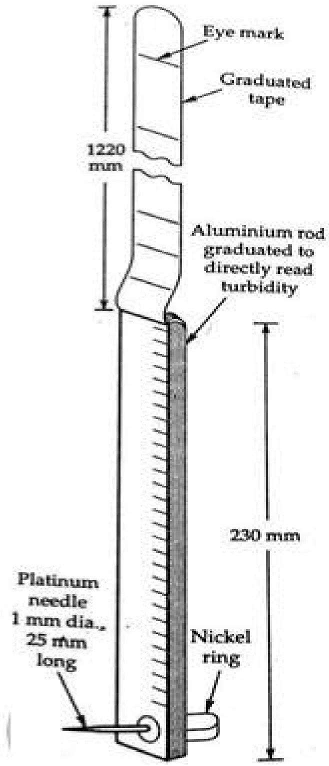


Figure 1: Turbidity Rod

Procedure:

- Lower the graduated Aluminium rod into the water keeping the eye at its upper end.
- The platinum needle is viewed
- The rod is then moved slowly downward and the reading on the rod is noted at which the needle just disappears. It gives the turbidity of water
- Lesser the length greater is the turbidity of water

Turbidimeter

- Measure turbidity in lab
- Turbidimeter works on the principle of measuring the interference caused by the water sample to the passage of light rays

1. Jackson's Turbidimeter
2. Baylis Turbidimeter
3. Nephelometers

Jackson's turbidimeter (Jackson's candle turbidimeter):

- Used to measure high turbidity in the range of 25 – 1000 ppm
- Consist of a glass tube placed on a tube holder fixed over a metallic stand provided with a candle at its bottom

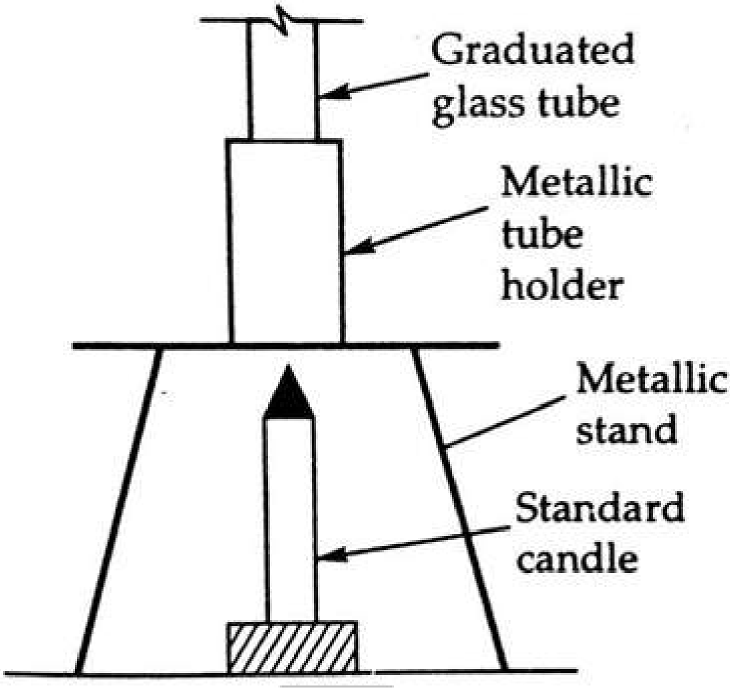


Figure 2: Jackson Candle Turbidimeter

Procedure:

- Light up the candle. Gradually add water to the glass tube
- The candle flame is observed from the top
- The height of water is noted at which the image of the candle flame disappears
- This height of water will provide a measure of turbidity in JTU (Jackson turbidity unit)
- Its application is limited to turbidity of water from natural sources. It cannot be applied to treated water since the lowest turbidity that can be measured using Jackson's turbidimeter is 25 ppm

Baylis turbidimeter

- Used to measure turbidity in the range of 0 – 10 ppm
- Consist of an iron box and two glass tubes placed vertically and are surrounded by blue cobalt plates at the bottom. Electric bulb is located to through light on the tubes.

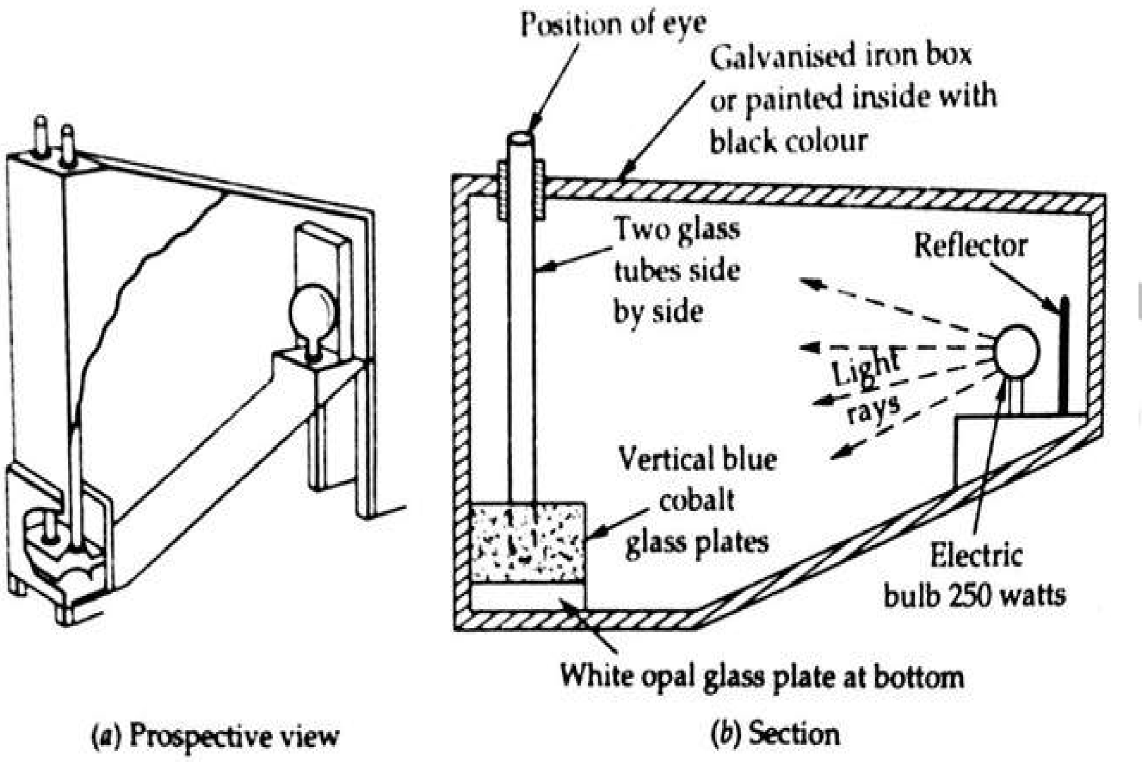


Figure 3: Baylis Turbidimeter

Procedure:

- Water to be tested is filled in one glass tube. In the second tube, water of known turbidity is filled
- Light is made to fall on the glass tube
- Observe the colour of both samples from the top
- Change the water in the second tube with different known turbidity until it matches the colour of water in the first tube.
- The turbidity of sample is thus the known turbidity of the water in the second tube
- Turbidity is represented in BTU (Baylis turbidity unit)

Naphelometers

- Used to measure low turbidity
- Observe light reflected at right angles
- Turbidity is represented in NTU (Naphelometers
- Turbidity unit) or in FTU (Formazine turbidity unit) since formazine is used as a standard suspension instead of silica

COLOUR

- It is caused by organic matter from decaying vegetation or some inorganic materials such as coloured soil, growth of algae, aquatic micro-organisms or metallic iron
- Colour is not objectionable from health point of view, but objectionable from aesthetic and psychological point of view
- Measured by comparing the colour of water sample with other standard glass tube (Nessler tube) containing standard solutions
- Standard unit for colour is that which is produced by 1 mg of platinum cobalt dissolved in 1 liter of water
- For precise determination of colour, Tintometer is used. It consists of an eye piece with two holes. A slide of standard coloured water is seen through one hole and the slide of water to be tested is seen from the their.
- Standard colour is replaced by another, till a matching is obtained and the colour intensity of sample is that of the standard solution
- Permissible limit for public use should not be greater than 20 ppm

TASTE or ODOUR

- It is due to dissolved organic matter, inorganic salts or dissolved gases
- It is represented in terms of Threshold odour number which indicate the dilution ratio at which the detection of taste and odour by human observation is lost

$$\text{Threshold number} = \frac{volume\ of\ raw\ water + volume\ of\ distilled\ water for\ dilution}{volume\ of\ raw\ water}$$

- Example: If 40 ml of sample is diluted to make 200 ml till it loses its taste and odour, then the threshold odour number is **5**
- Permissible limit: **1** to **3**

TEMPERATURE

- 10^oC is desirable
- Above 25^oC is objectionable

SPECIFIC CONDUCTIVITY

- Specific conductivity or electrical conductivity is a measure of total dissolved solids (TDS).
- Measured by conductivity sensor at 25oC
- Unit is mhos per centimeter or Siemen per centimeter
- TDS = Specific conductivity x conductivity factor
- Conductivity factor = 0.54 – 0.96 (0.67 is commonly used)

CHEMICHAL CHARACTERISTICS:

It includes:

- Total solids and suspended solids
- pH value
- Hardness
- Chloride content
- Nitrogen content
- Metal contents
- Dissolved gases

TOTAL SOLIDS AND SUSPENDED SOLIDS

- Total solids: Determined by evaporating a sample of water and weighing the residue left
- Suspended solids: Determined by filtering the water sample and weighing the residue left on filter paper
- Dissolved solids: the difference between total solids and suspended solids
- Total solids Permissible limit: 500 ppm

pH VALUE

pH indicate the logarithm of reciprocal of hydrogen ion concentration present in water

$$pH = \log_{10}\left(\frac{1}{H^+}\right)$$

It is an indicator of acidity or the alkalinity of water

- Higher value of pH : lower hydrogen concentration and thus alkaline
- Lower value of pH : Higher hydrogen concentration and thus acidic

- pH of pure water = 7
- pH > 7 : Alkaline
- pH < 7 : Acidic
- Alkalinity is caused by presence of bicarbonates of calcium and magnesium (**bicarbonate alkalinity**) or by carbonates sodium, potassium, calcium and magnesium (**carbonate alkalinity**) or hydroxides of sodium, potassium, calcium and magnesium (**caustic alkalinity**)
- Acidity caused by presence of mineral acids, free carbon dioxide, sulphates of iron and aluminium etc.
- pH is determined by potentiometer and also by colour indicators
- Potentiometer: measures potential exerted by hydrogen ion and indicate its concentration
- Colour indicator: added to te water and the colour produced is compared with the standard colour of known pH values
- Alkalinity effect: incrustation and sediment deposit in pipelines and difficult in chlorination
- Acidity effect: Tuberculation and corrosion
- Permissible limits: 6.6 to 8.5 for public supply

HARDNESS

- It is the characteristics of water which prevent the formation of leather or foam when mixed with soap
- Caused by presence of calcium and magnesium
- Effect of hardness: Greater soap consumption, scaling of boilers, corrosion and incrustation of pipelines, food become tasteless etc.

Type of hardness:

- Carbonate hardness (Temporarily hardness): Due to carbonates and bicarbonates of calcium and magnesium. It can be removed by boiling or by adding lime
- Non-carbonate hardness: due to sulphates, chlorides or nitrates of calcium and magnesium. It cannot be removed by simple boiling. It is removed by softening methods

Measurements of hardness:

- Hardness is defined as the calcium carbonate equivalent of calcium and magnesium ion present in water and is expressed in mg/l
- Measured by **EDTA** (Ethylene Diamine Tetraacetic acid test) and **Erichrome Black T** is the indicator and the hardness is calculated as follows

  Total hardness = $Ca^{++} (\frac{50}{20}) + Mg (\frac{50}{12})$

- Total hardness = Carbonate hardness + Non carbonate hardness
- If TH > alkalinity, then CH = Alkalinity and NCH = TH – CH
- If TH ≤ Alkalinity, then CH = TH and NCH = 0
- Hardness,
  - up to 75 ppm – Soft water
  - 75 to 200 ppm – Moderately hard
  - > 200 ppm – Hard

Permissible limits:

- For boiler feed water and for efficient cloth washing – hardness < 75 ppm
- For Public supplies – 75 to 115 ppm

CHLORIDE CONTENT

- Chlorides present in water in the form of sodium chloride (common salt) and may be due to leaching of marine sediments, pollution from sea water, industrial and domestic wastes etc.
- Measured by titrating with standard silver nitrate solution using potassium chromate as indicator
- Permissible limit: Should not exceed 250 mg/l

NITROGEN CONTENT

- Presence of nitrogen in water is an indication of presence of organic matter. Nitrogen occurs in the following forms:
  a) Free ammonia or ammonium nitrogen
  b) Albuminoid or organic nitrogen

c)Nitrites

d)Nitrates

Free ammonia: indicate first stage of decomposition of organic matter and release free ammonia and indicate recent pollution. Permissible limit for potable water should not exceed
0.15 mg/l. Measured by simple boiling the water and measuring the liberated ammonia gas bydistillation process.

Albuminoid Nitrogen: indicate the quantity of nitrogen in the form of un-decomposed organic matter. For potable water it should not exceed 0.3 mg/l. It is determined by boiling again the boiled water with potassium permanganate and measuring the ammonia gas liberated.

Kjedhal Nitrogen: Ammonia nitrogen + organic Nitrogen.

Nitrites: Indicate the presence of partly decomposed (not fully oxidised) organic matter. It is highly dangerous and its permissible limit is Nil. Measured by colour matching method and the colour is developed by adding sulphonic acid and napthamine.

Nitrates: indicate the presence of fully oxidized organic matter. Indicate old pollution Permissible limit is 45 mg/l. Excess Nitrates causes Methemoglobinemia (**Blue baby disease**). Measured by colour matching method and the colour is developed by adding phenol –di- sulphonic acid and potassium hydroxide.

METAL CONTENTS AND OTHER CHEMICAL SUBSTANCES

Metals and chemical substances are in excess cause harmful effect. Some of them are explained below. Metal and other substances are measured by colour matching methods with different indicators

Iron and manganese:

- Permissible limit : iron < 0.3 ppm

  : Manganese < 0.05 ppm

- Excess iron and manganese cause discolouration of clothes and incrustation of pipes

Copper:

- Permissible limit : 1 to 3 ppm
- Affects human lungs and respiratory organs

Sulphate:

- Permissible < 250 ppm
- Causes laxative effect on human body and diarrhea

Fluride:

- Permissible limit between 1 ppm and 1.5 ppm
- Fluride < 1 ppm : cause formation of fever cavities in the teeth
- Fluride > 1.5 ppm : causes fluorosis (mottling and discolouration of teeth) and deformation of bones

<u>DISSOLVED GASES</u>

It includes:

- Nitrogen: indicate presence of organic matter. It is not very important
- Hydrogen sulphide: gives bad taste and odour
- Carbon dioxide: indicate biological activity, impart bad taste and odour and cause corrosion of pipes

Dissolved oxygen (DO):

- Permissible limit for potable water be between 5 to 10 ppm
- Since DO is consumed by organic matter, DO less than its saturation level indicate presence of organic matter and pollution

- Biochemical oxygen demand: it is the amount of oxygen consumed by the organic matter for their oxidation.
- BOD is measured by dilution method; in which raw water is mixed with pure water saturated with known quantity of dissolved oxygen and is incubated for 5 days at 20oC. The difference between original oxygen content and the residual oxygen content will indicate the oxygen consumed by the organic matter in the raw water. Hence BOD is calculated as:

BOD = loss of oxygen x dilution factor

- Permissible limit of BOD for safe drinking water must be NIL

BIOLOGICAL CHARACTERISTICS:

BACTERIA – SINGLE CELL ORGANISM:

- Pathogenic bacteria: Harmful and cause series water borne diseases like cholera, typhoid etc.
- Non-pathogenic bacteria: Harmless

Based on oxygen necessities, bacteria are classifies as:

- Aerobic bacteria: Require oxygen for their survival
- Anaerobic bacteria: Require no oxygen for their survival
- Facultative bacteria: Survive with or without oxygen
- Coliform group are used as an indicator organism.
- Coliform group: Total coliform group and fecal coliform sub group (E-coli)

DETECTION OF COLIFORM BACTERIA:

The following methods are adopted:

- Membrane filter technique
- Multiple tube fermentation technique

Membrane filter technique:

Filter the water sample through a sterile membrane on which the bacteria will be retained. This filter is then put in a nutrient solution

- Nutrient solution for Total coliform: M-Endo broth
- Nutrient solution for fecal coliform: M-FC broth
- Then it is incubated at suitable conditions and visible colonies are counted with microscope

- ✓ Multiple tube fermentation technique:

It is divided into

a) Presumptive test

b) Confirmatory test

c) Fecal coliform presence test

a) **Presumptive test:** A broth containing lactose and a nutrient medium is placed in a series of test tubes. 5 tubes with 10 ml water sample, 5 tubes with 1 ml water sample and 5 tubes with 0.1 ml water sample. These tubes are incubated for 24 hours and formations of gas are noticed. Presence of gas will give an indication of presence of coliform. If the gas is not formed, it again incubated for another 24 hours. If no gas is evolved, it will show a negative test indicating absence of coliform

b) **Confirmatory test:** A portion from the tube showing positive presumptive test is mixed with brilliant green bile broth and incubated for 48 hours. If gas is evolved, it will be a positive confirmatory test confirming presence of coliform and if not, it will be a negative test.

After the confirmation, the density of coliform is determined and it is represented as MPN (Most probable Number)

c) **Fecal coliform presence test:** A portion from the tube showing positive presumptive test is mixed with E.C. medium broth and incubated for 24 hours. If gas is evolved, it will be a positive confirmatory test confirming presence of fecal coliform and if not, it will be a negative test.

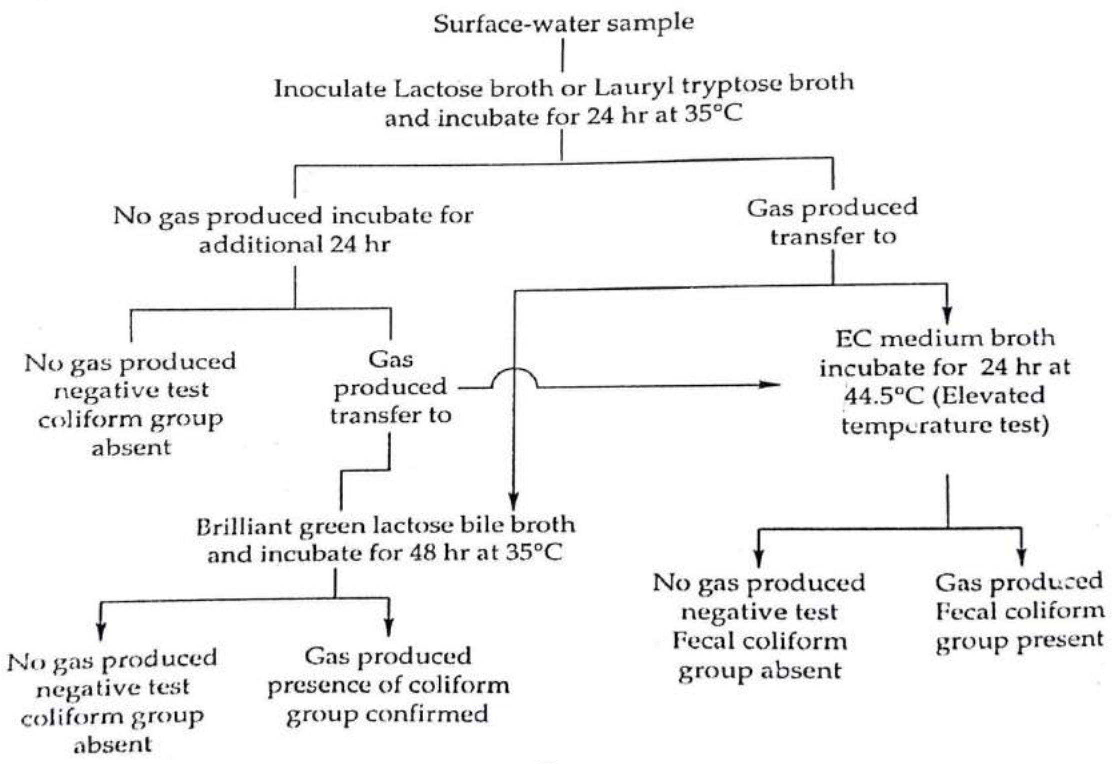


Figure 4: Schematic diagram for conducting coliform MPN Test

MPN (Most Probable Number)

- It is the bacterial density which is most likely to be present in water. Permissible value of MPN is NIL

Microscopic plants

- ✓ These are tiny plants present in water like algae, plankton, fungi, etc.

Water borne diseases

- Diseases primarily spread through contaminated water
- Bacterial infection: Typhoid fever, Cholera, diarrhea, bacillary dysentery
- Viral infection: Infection hepatitis, poliomyelitis, etc.
- Protozoal infection: Amoebic dysente

SUBSTANCE OR CHARACTERISTICS	DESIRABLE LIMIT	REMARKS
Colour, Hazen unit	5	Above 5, consumer acceptance
Odour	Unobjectionable	
Taste	Agreeable	
Turbidity, NTU	5	Above 5, consumer acceptance decrease
pH	6.5 to 8.5	Beyond this will affect the water supply scheme
Total hardness , mg/L	300	Encrustation on water supply structure and adverse effect on domestic use
Iron, mg/L	0.3	Affect taste and appearance. Affect domestic use and water supply system
Chlorides, mg/L	250	Affect taste and cause corrosion
Residual chlorine, mg/L	0.2	
Fluoride , mg/L	1	Cause fluorosis
Dissolved solids, mg/L	500	Gastro intestinal irritation
Magnesium, mg/L	30	Encrustation and adverse effect on domestic use
Calcium, mg/L	75	Encrustation and adverse effect on domestic use
Copper, mg/L	0.05	Discoloration and corrosion
Manganese, mg/L	0.1	Affect taste and appearance. Affect domestic use and water supply system
Sulphate, mg/L	200	Gastro intestinal irritation
Nitrate, mg/L	45	Metheamoglobinemia
Alkalinity, mg/L	200	Taste become unpleasant
Aluminium, mg/L	0.03	Cause dementia

MODULE-3

Treatment of water-Theory and principles of sedimentation tanks-Stoke's law-types of settling (type 1&type 2 only)-Coagulation–Mixing-Flocculation, Design of sedimentation tanks (circular and rectangular)- Clarrifloculators.

TREATMENT OF WATER

- Water treatment is any process that makes water more acceptable for a specific end- use
- The end-use may be drinking, industrial water supply, irrigation, river flow maintenance, Water recreation or many.
- Treatment removes contaminants and undesirable components, or reduces their concentration. So that the water becomes fit for its desired end-use
- Substances that are removed during the process of drinking water treatment include
  Suspended solids
  Bacteria
  Algae
  Viruses
  Fungi
  Minerals such as iron and manganese.

WATER TREATMENT PROCESSES

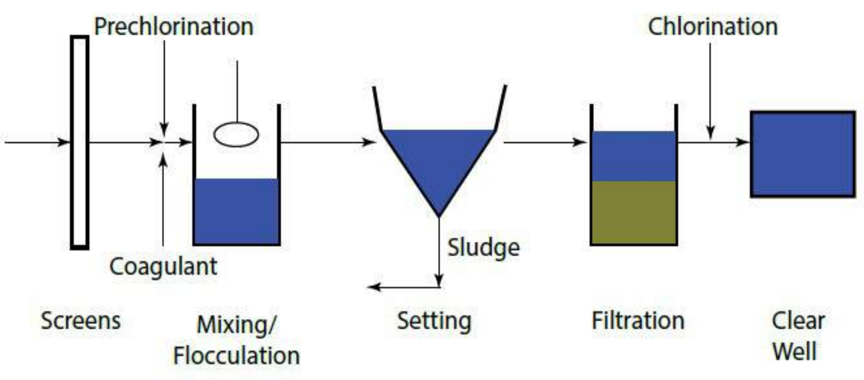


Fig. 7.1 Schematic layout of treatment plant

OBJECTIVE OF WATER TREATMENT PROCESSES

Following are the purpose of water treatment

1. To remove colour, turbidity and dissolved gas of water.
2. To remove objectionable taste and odour.
3. To remove the disease producing micro-organisms so that water is safe for drinking purpose.
4. To remove hardness of water.
5. To make water suitable for a wide variety of industrial purposes such as steam generation, brewing, dying etc.

METHODS OF WATERTREATMENT

1. Screening
2. Plain sedimentation
3. Sedimentation aided with coagulation
4. Filteration
5. Disinfection
6. Aeration
7. Softening
8. Miscellaneous treatment such as fluoridation,recarbonation,desalination etc

For surface waters, following are the treatment processes that are generally adopted.

Screening:

- This is adopted to remove all the floating matter from surface waters. It is generally provided at the front of intake point.
- Coarse screen: Placed infront of fine screen.it consist of parallel iron rods placed vertically or inclined at 45%-60%
- Fine screen: it consist of wire mesh .it removes fine materials,fine screens get clogged easily and to be cleaned frequently.

Aeration:

- Aeration is often the first major process at the treatment plant.
- This is adopted to remove objectionable tastes and odour and also to remove the dissolved gases such as carbon dioxide, hydrogen sulphide, volatile organic chemicals etc.
- The iron and manganese present in water is also oxidized to some extent.
- This process is optional and is not adopted incases where water does not contain objectionable taste and odour.

Sedimentation with or without coagulants:

- Sedimentation is a physical water treatment process using gravity to remove suspended solids from water.
- With the help of plain sedimentation, silt, sand etc. can be removed.
- However, with the help of sedimentation with coagulants, very fine suspended particles and some amount of bacteria can be removed

Filtration:

- The process of filtration forms the most important stage in the purification of water.
- Filtration removes very fine suspended impurities and colloidal impurities that may have escaped from the sedimentation tank.
- In addition to this, the micro-organisms present in water are largely removed.

Disinfection:

- Water disinfection means the removal, deactivation or killing of pathogenic microorganisms.
- It also prevents the contamination of water during its transit from the treatment plant to the place of its consumption.
- When microorganisms are not removed from drinking water, drinking water usage will cause people to fall ill.

Miscellaneous processes.

- These include water softening, desalination, removal of iron, manganese and other harmful constituents.
- Softening- Removes hardness of water.

- Fluoridation-Addition of soluble fluoride for controlling dental carries.
- Liming- Addition of lime for controlling acidity and reduce corrosive action.
- Recarbonation -Addition of carbon dioxide to prevent deposition calcium carbonate scale
- Desalination-Removal of excess salt

SEDIMENTATION

- The particles which do not change their shape, size and weight, while settling down in a fluid are known as discrete particles.
- The suspended impurities in water consists of discrete particles such as inorganic solids having specific gravity about 2.65 and organic solids having specific gravity 1.04.
- The particles having specific gravity more than 1.20 readily settle down at the bottom of the tank due to the force of gravity.
- This phenomenon of settlement is known as hydraulic subsidence.
- But the lighter particles cannot settle down due to force of gravity.
- Such particles are converted to settleable size by the application of some coagulant in water.
- The sedimentation tanks are designed to give complete rest to the flowing water or water is allowed to flow at a very low velocity.
- The heavier inorganic impurities settle at the bottom of tanks and lighter inorganic impurities float on the surface of liquid level.
- The former impurities are removed from bottom while latter impurities are removed from the top.

Plain sedimentation.

- When the impurities are separated from suspending fluid by the action of natural forces alone; ie. by gravitation and natural aggregation of the settling particles, the operation is called plain sedimentation

Sedimentation with coagulation

- Very fine colloidal particles cannot come together and get settle down by the above treatment since they have negative charge associated with them, which impart stability to the colloidal system formed.
- Hence they are removed by addition of chemicals called coagulants to water before sedimentation.
- These on dissolution in water produce cations which can neutralize the negative charge of the particles
- Hence from an insoluble gelatinous flocculent precipitate, which adsorb and forming bigger floc and this get settle down easily under the force of gravity.

Theory of sedimentation

- The basin in which the flow of water retarded is called sedimentation tank or settling tank or clarifier. The theoretical average time in which water is retared in the tank is called detension time
- The process of settlement of a particle is obstructed or opposed by the following three forces.

i. The velocity of flow

- The velocity of flow carries the particle horizontally. The greater the flow area, the lesser is the velocity and hence more easily the particle will settle down

iii. The size, shape and specific gravity of the particle

- The greater is the specific gravity, more readily the particle will settle. The size and shape of the particle also affect the settling rate.

ii. The viscosity of water in which the particle is travelling

- The viscosity varies inversely with temperature.
- Warm water is less viscous and, therefore less resistance to settlement.
- So high viscous water resist settling of particles.

Types of settlings

Particles may settle out of a suspension in the following four ways, depending upon the concentration of the suspension and the flocculating properties of particles (Fig.7.2).

1. Type I: Discrete particle settling

2. Type II: Flocculent particles settling

3. Type III: Hindered or zone settling

4. Type IV: Compression settling

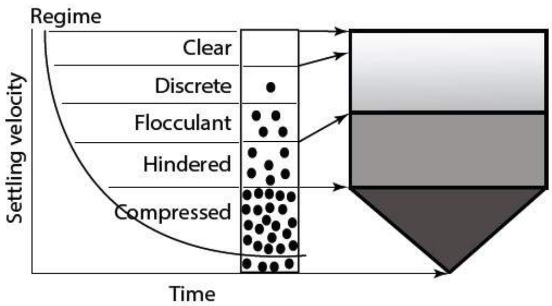


Fig. 7.2 Types of settling

1. Type I: Discrete particle settling - Particles settle individually without interaction with neighboring particles.

2. Type II: Flocculent Particles – Flocculation causes the particles to increase in mass and settle at a faster rate.

3. Type III: Hindered or Zone settling –The mass of particles tends to settle as a unit with individual particles remaining in fixed positions with respect to each other.

4. Type IV: Compression – The concentration of particles is so high that sedimentation can only occur through compaction of the structure.

In water treatment, only type I and type II settling are encountered

Type I Settling

- Type I sedimentation is concerned with the settling/removal of non flocculating, discrete particles from water.
- In this type of settling the size, shape and specific gravity of the particles do not change with time and settling velocity remains constant.
- When a discrete particle is placed in a quiescent fluid, it will accelerate until the frictional resistance FD of the fluid equals the impelling force FI acting on the particle.
- At this stage, the particle attains a uniform or terminal velocity and settles down with this constant velocity known as settling velocity.

The impelling force (F_I) is evidently equal to the effective weight of the particle:

$$F_I = (\rho_p - \rho) g V \qquad .....(7.1)$$

Where,

ρ_p= Mass density of particle

ρ= Mass density of fluid

g = Acceleration due to gravity

V= Volume of Particle, $\frac{\pi}{6}d^3$ Where, d is the diameter of spherical particle

a. Newton's Law

The drag force F_D depends on

i. Dynamic viscosity

ii. Mass density ρ of the fluid and

iii. shape and size of the particle

The drag force is given by Newton's law for frictional drag in the following form:

$$F_D = C_D.A.\frac{\rho V_s^2}{2} \qquad ....(7.2)$$

Where, F_D = Drag force

C_D = drag coefficient

A = projected area of the particle $\frac{\pi}{4}d^2$.

Equating the two, we get an equation for the settling velocity in the form

$$V_s = \sqrt{\frac{4g(\rho_s - \rho)d}{3C_D\rho}} \qquad .....(7.3)$$

or closely,

$$V_s = \sqrt{\frac{4g(S_s - 1)d}{3C_D}} \qquad .....(7.4)$$

Where, S_S = specific gravity of the particle.

Above equations requires the determination of drag coefficient C_D which is related to Reynolds number R.

b. Stokes Law

Stoke's law for the drag of small settling spheres in a viscous fluid, neglecting the inertia force is given by

$$F_D = 3\pi\mu V_s . d$$

Equating this to Eq. 7.2 is given by

$$C_D = \frac{24}{R} \qquad \text{.....(7.5)}$$

Substituting this value of C_D in Eq. 7.3 we get

$$V_s = \frac{1}{18}\frac{g}{\mu}(\rho_s - \rho)d^2$$

$$V_s = \frac{1}{18}\frac{g}{V}(S_s - S)d^2$$

$$V_s \approx \frac{1}{18}\frac{g}{\upsilon}(S_s - 1)d^2$$

Where,

v = Kinematic viscosity of water in centistokes which varies with temperature of water.

substituting ∴ the value of C_D in eq 7.3.

$$V_s = \sqrt{\frac{4}{3} \times \frac{g}{C_D} \frac{(\rho_s - \rho)}{\rho} d}$$

$$V_s = \sqrt{\frac{4}{3} \times g \times \frac{R}{24} \frac{(\rho_s - \rho)}{\rho} \times d}$$

$$V_s = \sqrt{\frac{4}{3} \times g \times \frac{\rho V_s \times d}{24 \times \mu} \frac{(\rho_s - \rho) d}{\rho}}$$

$$V_s = \sqrt{\frac{1}{18}\frac{g}{\mu} d^2 (\rho_s - \rho) V_s}$$

$$V_s = \sqrt{\frac{1}{18} \times \frac{g}{\mu} (\rho_s - \rho) d^2 V_s}$$

Square both sides

$$V_s^2 = \left(\sqrt{\frac{1}{18} \times \frac{g}{\mu} (\rho_s - \rho) d^2 V_s}\right)^2$$

$$V_s^2 = \left(\sqrt{\frac{1}{18} \times \frac{g}{\mu} (\rho_s - \rho) d^2}\right)^2 \left(\sqrt{V_s}\right)^2$$

$$V_s^2 = \left(\sqrt{\frac{1}{18} \times \frac{g}{\mu} (\rho_s - \rho) d^2}\right)^2 \left(\sqrt{V_s}\right)^2$$

$$V_s^{2} = \frac{1}{18}\frac{g}{\mu}(\rho_s - \rho) d^2 V_s$$

$$\boxed{V_s = \frac{1}{18} \times \frac{g}{\mu} (\rho_s - \rho) d^2}$$

Type II Settling

- Type II settling is the settling of particles that flocculate as they settle.
- The process of flocculation produces larger particles and settles at a faster rate.
- Settling of particles in coagulation cum sedimentation tank is an example for type II settling.

Classification of sedimentation tanks

Depending upon the nature of working, the sedimentation tanks are of the following two types.

i. Fill and draw types tanks

ii. Continuous flow type tanks

Fill and draw type tanks

- These are also known as intermittent type sedimentation tanks.
- The water is filled in the tanks and it is then allowed to rest for a certain time.
- During the period of rest, the particle in suspension will settle down at the bottom of tank.
- The clear water is then drawn off and tank is cleaned of silt and filled again. Generally, a detention time of 24 hours is allowed.
- At the end of the period, the clear water drawn off through the outlet valve.
- The plan and section of fill and draw type tank is given below.

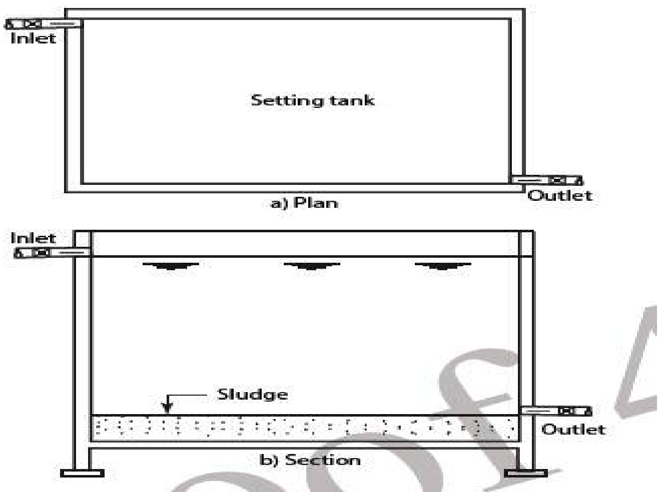


Fig. 7.3 Fill and draw type tank

Continuous flow type tanks

- In the continuous flow type, the water continuously keeps on moving in tank, though with a very low velocity during which time the suspended particles settle at the bottom before they reach the outlet.
- There are two types of continuous flow tanks.
  - ✓ Horizontal flow tanks
  - ✓ Vertical flow tanks

a. Horizontal flow tank.

- In the horizontal flow type, the tank is generally rectangular in plan having length equal to at least twice the width.
- The water flows practically in the horizontal direction, with a maximum permissible velocity of 0.3 m/sec. These are further divided in to
  - ✓ Rectangular tanks
  - ✓ Circular tanks
- which are further classified as
  - ✓ Radial flow tanks
  - ✓ Circumferential flow tanks

b) Vertical flow tanks

- Vertical flow type sedimentation tanks are generally circular in shape and flow takes place in vertical direction.
- Hoper bottom is provided at the bottom of the tank to dispose the collected sludge

PLAIN SEDIMENTATION TANKS

Plain sedimentation tanks are usually of the following three types:

a) Rectangular tanks

b) Circular tanks

c) Hopper Bottom tanks

a. Rectangular sedimentation tank

- In this type of tank, its capacity depends upon the volume of water to be treated.
- The length depends on the velocity of flow and detention period.
- The detention period may vary from 4-6 hours. The width of the tank varies from 10m – 12m, and the depth of the tank varies from 2m to 4m.
- Here, the length of travel of the particles is increased by providing baffle walls.
- Thus, the velocity of flow is much reduced to maintain the designed detention period.
- Due to the low velocity of flow the heavier particles are settled down at the bottom of the tank as sludge.
- After some interval of time, the sludge is removed through the sludge removal pipe by opening the valve as shown in Fig

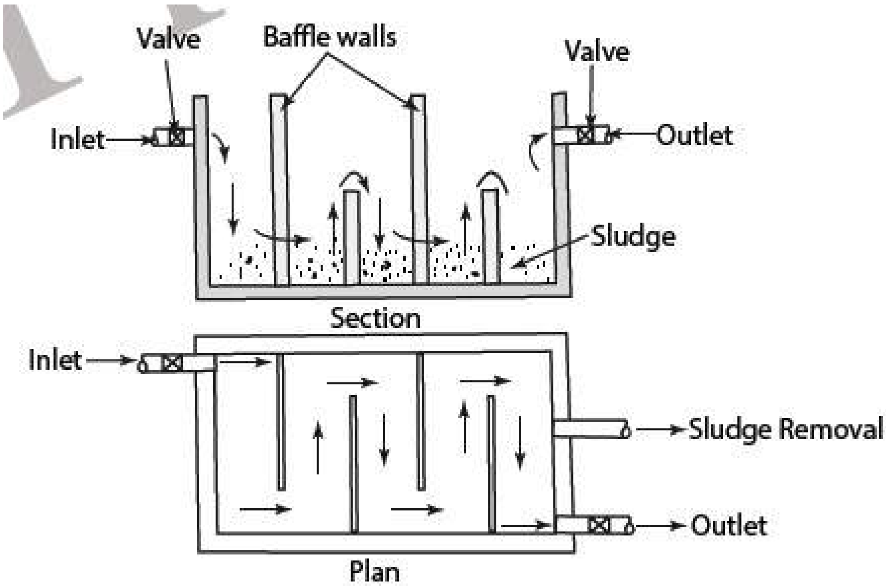
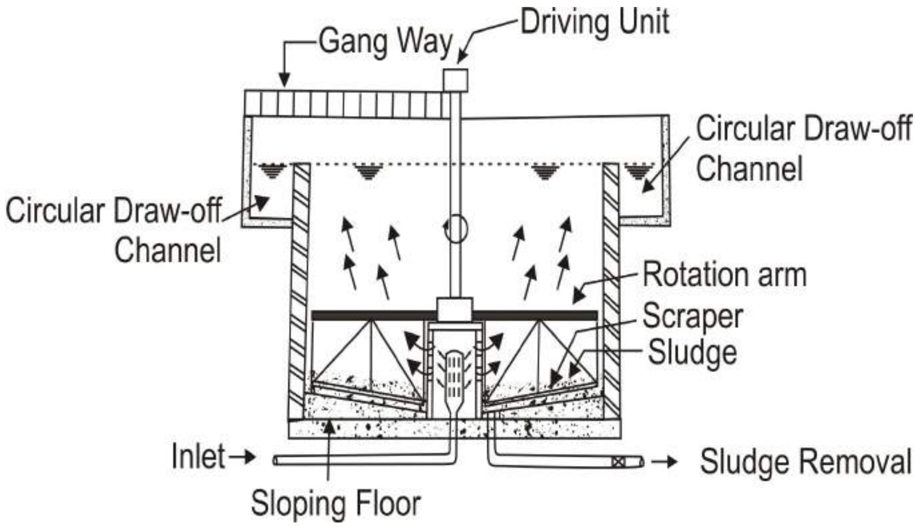


Fig 7.4 Rectangular sedimentation tank

Circular sedimentation tank

- The circular sedimentation tank may be radial or spiral flow.
- But the tank with radial flow is commonly adopted.
- In this tank, the water is allowed to enter through the pipe which is provided at its centre.
- The water flows upwards gently through the openings.

- The water is collected at the circular draw-off channel from where it is taken to next unit through the outlet pipe as shown in Fig.
- The sediments or sludge are settled down at the bottom of the tank.
- A driving unit is provided for rotating an arm which consists of scrapper.
- The circular motion of the scrapper helps the sludge to discharge through the sludge removal pipe.



Hopper bottom sedimentation tank

- In this tank, the water is allowed to enter through the centrally placed inlet pipe and is deflected downwards by the action of a deflector box.
- The water flows downwards inside the box and then it rises in upward direction through the opening between the box and the wall of the tank.
- When the water rises in upward direction.
- the particles having specific gravity more than 1.0 cannot follow the path and ultimately settle down at the bottom of the tank due to the property of hydraulic subsidence
- The sludge settles at the bottom of the hopper, from where it is removed with the help of a sludge pipe connected to a sludge pump.

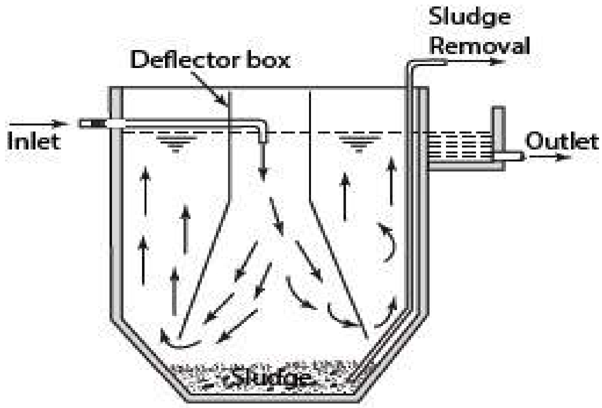


Fig. 7.6 Hopper bottom sedimentation tank

Design concept of plane sedimentation tank

(i) Overflow rate / surface flow rate :-

Quantity of water passing per hour per unit area of sedimentation tank

$$V_0 = \frac{Discharge}{surface\ area}$$

$$\frac{Q}{B * L}$$

$$\frac{V/T}{B * L}$$

$$\frac{(B * L * D)/T}{B * L}$$

$$\frac{D}{T}$$

$V_0 =$ 500 to 750 litre/hr/m^2 for type-I settling

$V_0 =$ 1000 to 1250 litre/hr/m^2 for type-II settling

(ii) Depth:-

- 1.8 to 6 m (usually 3 to 4.5)

- For tank without mechanical scrapper give additional depth for storage of sludge called sludge zone (0.8 to 1.2 m)
- Provide freeboard of 0.5 m to avoid the overflow

(iii) Detention period

- The time where water retarded in tank
- t = $\frac{volume\ or\ capacity\ of\ tank}{rateof\ flow\ or\ discharge}$
- for rectangular section , t=$\frac{C}{Q}$ =$\frac{L*B*H}{Q}$
- For circular section ,t=$\frac{d^2(0.011d+\ .785H)}{Q}$
- For type – 1 tank t = 4 to 8 hours
- For type – 11 tank t = 2 to 4 hours

(iv) Width of tank (B)

- Less than 12 m

(v) Horizontal flow velocity (V)

- V= $\frac{L}{t}$ L= length and t= time
- V = 0.15 to 0.9 m/minute (usually 0.3 m/ min)

Q1 The maximum daily demand at a water purification plant has been estimated as 12 million litres per day. Design the dimensions of a suitable sedimentation tank (fitted with mechanical sludge removal arrangements) for the raw supplies, assuming a detention period of 6 hours and the velocity of flow as20 cm per minute.

Solution: Quantity of water to be treated in 24 hours = $12*10^6$ litres

Quantity of water to be treated during the detention period of 6 hours

$$= [\frac{12*10^6}{24} * 6] \text{ litres } = 3*10^6 \text{litres}$$

$$=3*10^3 \text{ cubic metres} = 3000 \text{ cu.m.}$$

Therefore capacity of the tank required = 3000 cu.m.

Velocity of flow to be maintained through the tank = 20cm /minute = 0.2 m/minute

The length of the tank required = velocity of flow* detention period

$$= 0.2* (6*60) = 72 \text{ m}$$

Cross-sectional area of the tank required= $\frac{capacity\ of\ the\ tank}{lengt\ \ of\ the\ tank}$

$$= \frac{3000}{72} \text{ m}^2 = 41.67 \text{ m}^2\text{, say } 41.7 \text{ m}^2$$

Assuming the water depth in the tank as 4 m, the width of the tank required

$$=\frac{41.7}{4} = 10.42\text{m, say } 10.5 \text{ m}$$

Using freeboard of 0.5m, the overall depth = 0.5+4 = 4.5 m

Hence, a rectangular sedimentation tank with an overall size of 72m*10.5m*4.5m

<u>Alternatively</u>

Instead of assuming the depth ,we may assume an overflow rate, say as 600 litres/hr/m^2

Therefore $\frac{Q}{B*L}$ = 600litres/hr/m^2 (i.e.between 500 to 750litres/hr/m^2)

But Q $=\frac{12*10^6}{24}$ litres/hr = 0.5 litres/hr

Therefore B*L = $\frac{Q}{600} = \frac{0.5*10^6}{600}$ = 833 m^2 or B=$\frac{833}{72}$ = 11.6m

Therefore the depth = $\frac{3000}{72*11.6}$ = 3.6 m

Hence we can alternatively use a tank of dimensions = 72m*11.6m*(3.6+0.5)m overall depth

72m*11.6m*4.1m size

Q2: Two million litres of water per day is passing through a sedimentation tank which is 6m wide,15 m long and having a water depth of 3m.(a) find the detention time of the tank.(b) what is the average flow velocity through the tank (c) if 60 ppm is the concertration of suspended solids present in turbid raw water, how much dry solids will be deposited per day in the tank, assuming 70%removal in the basin, and average specific gravity of the deposit as 2. (d) Compute the overflow rate.

Solution: the capacity of the tank = L*B*D =15m*6m*3m = 270 m^3

Discharge passing through the tank ,Q= 2 Million litres per day

$$=2*10^6 \text{ litres per day} = \frac{12*10^6}{24} \text{ litres per hour}$$

$$= 83.33*10^3 \text{ litres per hour} = 83.33 \text{ cu.m /hr}$$

Detention time = $\frac{capacity\ of\ the\ tank}{discharge} = \frac{270}{83.33}$ hours =3.24 hours

(b) Average velocity of flow through the tank = $\frac{discharg}{cross-section\ area\ (B*H)} = \frac{83.33}{6*3}$ = m/hr

$$= \frac{83.33}{6*3} * \frac{100}{60} \text{ cm/minute} = 7.72 \text{ cm/minute}$$

(c) Quantity of water passing per day= 2 million litres = $2*10^6$ litres

Concentration of suspended solids = 60 ppm

Therefore quantity of suspended solids entering the tank per day =$2*10^6*\frac{60}{10^6}$ litres= 0.12cu.m

Given the average specific gravity of the deposited material as 2,we have its density as 200Kg/m^3

Therefore mass of suspended solids deposited (with 70% removal) per day

$$= (0.12*0.7)(2000) \text{ Kg} = 168 \text{ Kg}$$

(d) overflow rate = discharge per unit plan area

$$=\frac{Q}{B*L} = \frac{83.33*10^3 \text{litres/hr}}{6*15\ m^2} = 926 \text{ litres/her/}m^2$$

Q3:A circular sedimentation tank fitted with standard mechanical sludge removal equipment is to handle 3.5 million litres per day of raw water. If the detention period of the tank is 5 hours,and the depth of the tank is 3m,what should be the diameter of the tank.

Solution: Quantity of water to be treated in per day = $3.5*10^6$ litres

Thereforequantity of water to be treated during the detention period of 5 hours. i.e the capacity of the tank

$$= [\frac{3.5*10^6}{24} * 5] \text{ litres } = 729*10^3 \text{litres} = 729 \text{ cu.m}$$

The capacity of the circular tank of depth H and diameter d is given by

$$\textit{Volume} = d^2\ (0.011d+0.785H) \qquad (H = 3m)$$

$$729 = d^2\ (0.011d+0.785*3)$$

$$729 = d^2\ (0.011d+2.255)$$

Solving this equation by Hit and trial, we get d=17.3m

SEDIMENTATION AIDED WITH COAGULATION (CLARIFICATION)

- In plain sedimentation the heavier particle settle down. However, fine particles take many hours or some days to settle down.
- Colloidal particles which are of size finer than 0.0001 mm carry electrical charges on them.
- These are continuous in motion and will never settle down under gravity.
- As it is not possible to have detention period in the sedimentation tank more than 3 to 4 hours.
- They can be removed easily by increasing their size by changing them into flocculated particles
- For this purpose, certain chemical components called coagulants are added to the water.
- Which on thorough mixing form a gelatenous precipitate called floc
- The very fine colloidal particle present in water, get attracted and absorbed in these flocs, forming the bigger sized flocculated particles

- **Coagulation** is a chemical technique which is directed towards the destabilization of charged particles
- **Flocculation** is the slow mixing technique which promotes the agglomeration of the stabilized particles
- For all the practical purposes, however the entire process of addition of chemicals (coagulants) and mixing (flocculation) is usually referred to as **coagulation.**
- The coagulated water is finally made to pass through the sedimentation tank, where the flocculated particle settle down and are thus removed.
- The use of coagulants is generally necessary for clarifying raw waters containing turbidities greater than 30 to 50 mg/l
- But in actual practice, plain sedimentation is rarely used these days.
- The coagulation before sedimentation is almost universally adopted in all the major treatment plant.
- The chemically assisted sedimentation comprises several separate processes of treatment which go to make up the complete system known as **clarification.**
- It is achieved in three stages:
    - ❖ Addition of coagulants
    - ❖ Formation of floc
    - ❖ Sedimentation

Principle of coagulation

The principle of coagulation has been explained by the following phenomenon.

a) Floc formation

b) Electric charges

a. Floc formation

- When a coagulant is added to the water and mixed thoroughly, a thick gelatinous precipitate is formed which is insoluble in water.
- This precipitate is called floc. As the floc settle down, it attracts and arrests the colloidal particles and brings them down.

b. Electric charges

- It is observed the ions of floc posses positive charge.
- Colloidal particles are negatively charged ions. So, the floc attracts the colloidal particles while it travels towards the bottom of tank.

Common Coagulants

- Various chemicals such as alum, iron salts like ferrous sulphate, ferric chloride ,ferric sulphate are generally used as coagulant
- These chemicals are most effective when water is slightly alkaline
- In the absences of such an alkalinity in raw supplies, external alkalies like sodium carbonate or lime etc are added to the water
- So as it make slightly alkaline and thus to increase the effectiveness of the coagulant.
- The following are the usual chemicals which are commonly used for the coagulation.
    1. Aluminum Sulphate or alum
    2. Chlorinated copperas
    3. Ferrous Sulphate and Lime
    4. Magnesium Carbonate
    5. Polyelectrolyte and
    6. Sodium Aluminate

1.Aluminum Sulphate (Alum)

- The chemical composition of Aluminum Sulphate is $Al_2(SO4)_3\ 18H_2O$.
- It is commonly known as alum. It is available in the form of a solid lump, but applied in a powder or liquid form.
- It is very effective if bicarbonate alkalinity is present in water. If the water possesses no alkalinity, some amount of lime is to be added to water.
- When alum is mixed with water, a chemical reaction takes place and aluminum hydroxide ($Al(OH)_3$), calcium sulphate ($CaSO_4$) and carbon dioxide (CO_2) are formed.
- The aluminum hydroxide is insoluble in water and it forms the floc.
- It is effective between pH value 6.5 and 8.5.

- The dosage of this coagulant depends on various factors such as turbidity, colour, pH-value, etc.
- In practice the dosage of alum varies from 10 to 30 mg per liter.
- Alum is preferred over other coagulants because it reduces taste and odour in addition to turbidity in water.

2.Ferrous Sulphate and lime

- The ferrous sulphate and lime when mixed with water, a chemical reaction takes place and ferrous hydroxide [$Fe(OH)_2$] is formed.

- This compound is again oxidized by the dissolved oxygen in water and finally ferric hydroxide is formed. This ferric hydroxide forms the floc.

3. Chlorinated Copperas

- When chlorine is mixed with the solution of Ferrous sulphate, a chemical reaction takes place which forms ferric sulphate [$Fe2(SO_4)_3$] and ferric chloride [$FeCl_3$].
- The combination of these two compounds is known as chlorinated copperas. Both the compounds are effective for the formation of floc.
- Sometimes, ferric sulphate and ferric chloride may be applied independently with lime.
- In that case, ferric hydroxide [$Fe(OH_3)$] is formed which is also effective for the formation of floc.
- The ferric sulphate is effective for pH-value 4 to 9 and ferric chloride is effective for pH value 3.5 to 6.5.

4.Magnesium carbonate and lime

- When magnesium carbonate and lime are dissolved in water, magnesium hydroxide and calcium carbonate are formed.

- Both these are soluble in water, resulting in the formation of sludge which is in slurry form. Due to this, it is not commonly used.

5.Polyelectrolytes

- Polyelectrolytes are high molecular weight water-soluble polymers.
- The amount of polyelectrolyte used is very small in reaction to the amount of primary coagulant.
- The usual dosage of polyelectrolytes is 1ppm.

6.Sodium Aluminate

- Besides alum and iron salts, Sodium aluminate $Na_2Al_2O_4$ is also sometimes used as coagulant
- This chemical dissolved and mixed with water, reacts with salts of magnesium and calcium present in raw water, resulting in the formation of precipitate of calcium or magnesium aluminate.
- This coagulant is about one and half times costlier than alum and generally avoided for treating.
- This coagulant removes both temporary and permanent hardness, and is effective for a pH range of 6 to 8.5 naturally available in water**.**

COMPARISON OF ALUM AND IRON SALYS (AS COAGULANT)

- Iron salts produce heavy floc and can, therefore removed much more suspended matter than the alum.
- Iron salts, being good oxidizing agents, can remove hydrogen sulphide and its corresponding tastes and odours from water
- Iron salts can be removed over a wide range of pH values
- Iron salts cause staining and promote the growth of iron bacteria in the distribution system.
- Iron salts imparts more corrosiveness to water than that which is imparted by alum
- The handling and storing of iron salts require more skill and control, as they corrosive and deliquescent. Whereas, no such skill supervision is required for handling alum.

CONSTITUENTS OF COAGULATION SEDIMENTATION PLANT

- It is also known as coagulation plant or clariflocculator
- Four units of the plants are
  1. Feeding device
  2. Mixing device or mixing basin
  3. Flocculation tank or flocculator
  4. Settling or sedimentation
- The coagulant its, first of all fed (either dry or solution form) into raw water through the **feeding device**
- This mixture is then thoroughly mixed and agitated in the **mixing basin**
- The floc which is formed in the mixing basin is then allowed to consolidate in the **flocculation tank.**
- The flocculated water is then passed into the **sedimentation tank** where these flocculated particles settled down and be removed

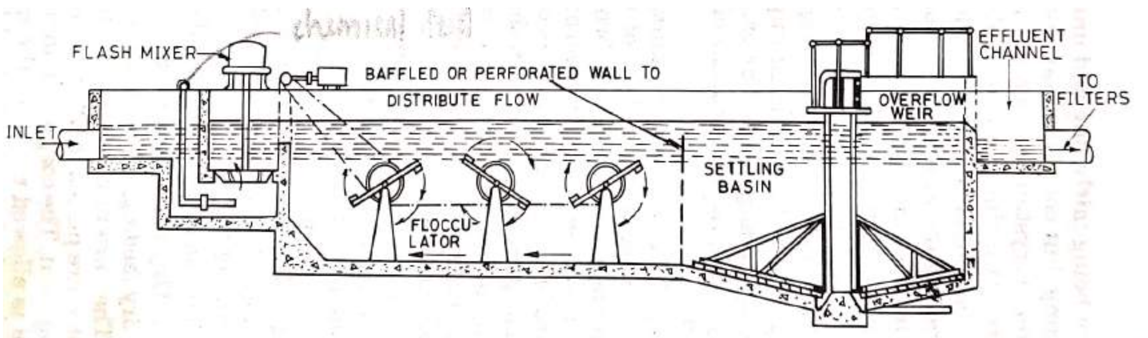


Fig. 9.17. Dorr Co. Clariflocculator.

- It consists of coagulant feed, flash mixer, flocculator and clarifier as a single unit.
- The coagulant is fed which is then mixed in the flash mixer, flocculation takes place in the flocculator and settling of particles take place in clarifier within a single unit called dorr clariflocculator.
- The water from the flocculator is taken on to the clarifier whose design is same as those of plain sedimentation tank.

- Here the water is retained for sufficient period of time for the purpose of settlement of floc along with the suspended particles.
- 2-2.5 hrs is adopted as the detention period with Surface Overflow rate (SOR) 30-40 $m^3/day/m^2$.

Coagulation – sedimentation may help in

- Removing turbidities up to as low value as10-20 mg/L
- Reduce bacteria in water
- Reduce B- coli index by 70%

1.Feeding devices

- They are two types
    1. Dry feeding device – coagulant fed in powdered form
    2. Wet feeding device- coagulant fed in solution form

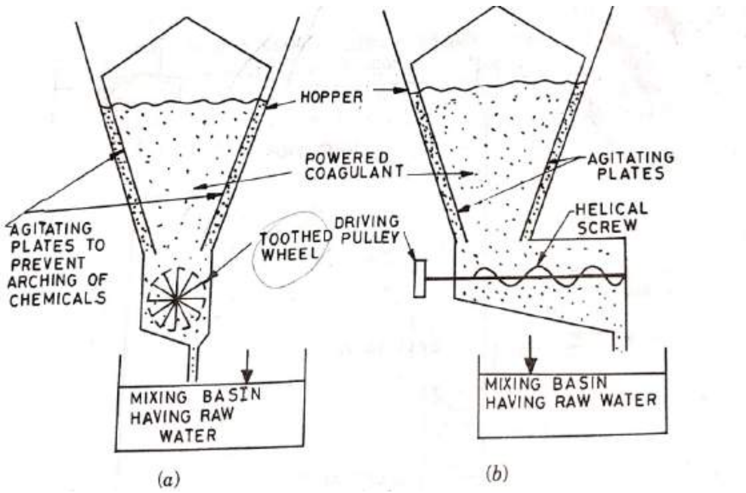
Choice between these two depends upon:-

1. The characteristics of coagulant and the convenient with which it can be applied
    - ✓ Chemical which clog or which are non- uniform cannot be fed by dry device
    - ✓ Alum can be fed by dry feeding
    - ✓ Cooperas by wet feeding because water crystallization present in it may change by temperature.
2. Amount of coagulant to be added
    - ✓ If the dose s very small ,then it is fed by wet feeding.
3. Cost of coagulant and size of plant
    - ✓ It the plant is small then dry feeding is may be choose, because dry feeding is cheaper and larger plant use wet feeding.

Dry feeding device

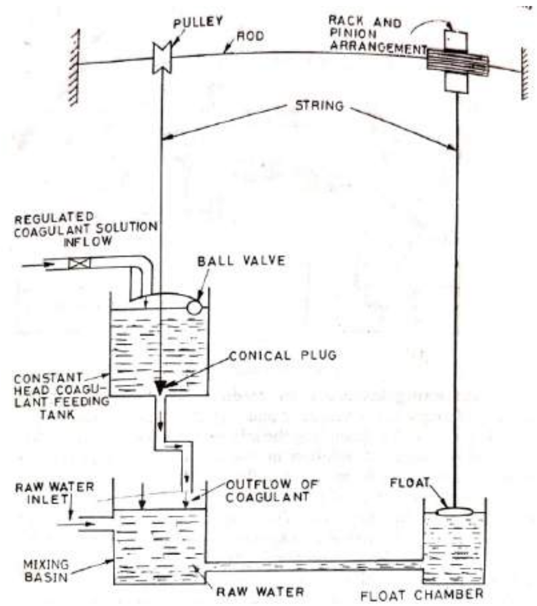
- Consist of a tank with hopper bottom
- The coagulant in the powdered form is filled in the hopper tank and is allowed to fall in the mixing basin

- Agitating plates are placed inside the tank, so as to prevent the arching of the coagulant
- Its dose is regulated by the speed of a toothed wheel or by helical screw.



Wet feeding device

- The solution of required strength of coagulant is prepared and stored in a tank, form where it is trickle down in to the mixing basin.
- The level of solution in the tank and rate of flow is adjusted by means of float valve and a conical valve arrangement.



- When the rate of inflow of raw water changes, the rate of outflow of coagulant must also change.
- In order to make these two flows in proportion to each other a conical plug type arrangement such as shown in above figure may be used.
- The working of a conical arrangement is very simple.
- The mixing basin and the float chamber are interconnected together, so that the water remains the same in both of them.
- As the flow of raw water increase, the depth of water, and therefore its level increases in the mixing tank.
- Correspondingly, the water level in the float chamber increases and thereby, lifting the float of the float chamber.
- As the float rises, the pinion and pulley rotates in the same direction, thereby lifting the conical plug and allowing more quantity of coagulant solution to fall down into the mixing basin
- When the flow of water decreases, the conical plug ,descends down and allows the feeding to continue at a lower rate

Dry feeding Vs wet feeding

WET FEEDING	DRY FEEDING
Generally costlier then dry feeding	Generally cheaper then dry feeding
Can be easily adjusted and controlled	Controlling is difficult
Additional tank for preparing and storing of solution	No additional tank is required
Extra labour required	Extra labour not required
Eg: copperas coagulant	Eg: alum

2.MIXING DEVICES

- After the addition of the coagulant to raw water, the water needs to be thoroughly and vigorously mixed so that the coagulant gets fully dispersed into the entire mass of water.
- The various mixing devices indicated below are adopted.

- ✓ Mixing basins with baffle walls
- ✓ Mixing basins with mechanical means
- ✓ Mixing channel
- ✓ Hydraulic channel
- ✓ Compressed air
- ✓ Centrifugal pumps

1. Mixing basins with Baffle Walls

- These are rectangular basins or tanks which are provided with baffle walls.
- The disturbance created by the presence of baffle walls in the path of the flowing water causes vigorous agitation of water
- Which results in thorough mixing of water with the coagulant.
- Such basins are of two types as indicated below.

  a) Horizontal or round the end type

  b) Vertical or over and under type
- Horizontal flow type is more preferred due to its ease of cleaning

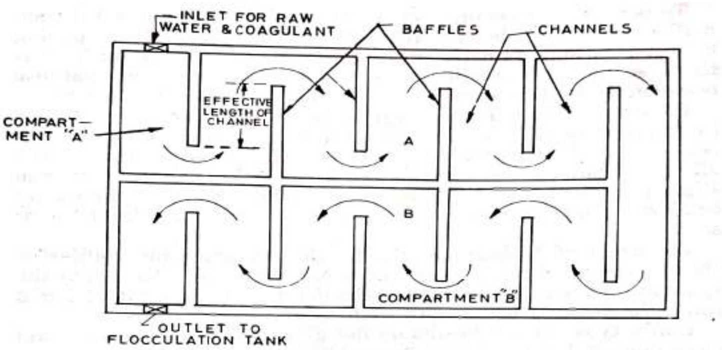


Fig. 9.20. Plan of "Around the end baffle type" mixing basin.

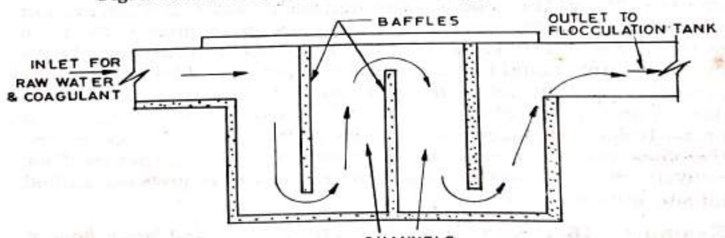


Fig. 9.21. Sectional elevation of "Over and under the baffle" type mixing basin.

2. Mixing basin with mechanical devices

- It consist f a rectangular tank with a flash mixer.
- Flash mixer consist of an impeller device by an electric motor and it revolve at high speed.
- The coagulant is brought by the coagulant pipe and is discharged just under the rotating fan.
- The raw water is separately brought from the inlet end and is deflected towards the moving impeller by a deflecting wall.
- The thoroughly mixed water is taken out from the outlet end.
- A drain valve is also provided to remove the sludge from the bottom of the flash mixer.

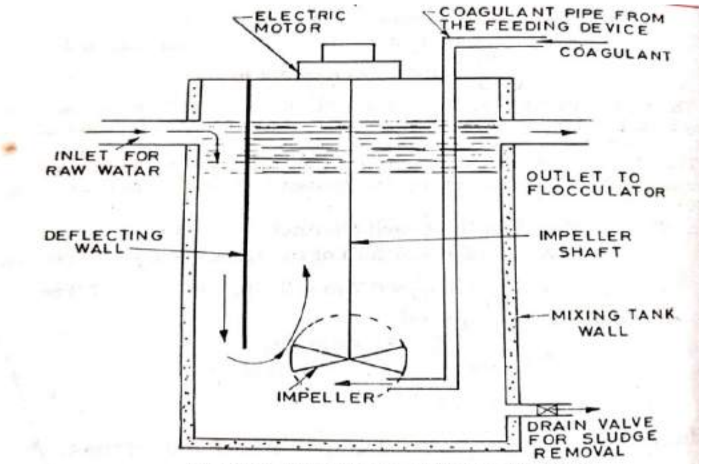


Fig. 9.22. Mixing basin with a flash mixer.

3. Mixing Channel

- In a mixing channel, the coagulant is fed through the feeding tank which then strikes with the vertical baffles provided creating a violent agitation which causes thorough mixing of water with the coagulant.
- Flume is provided to create a hydraulic jump to create turbulence.

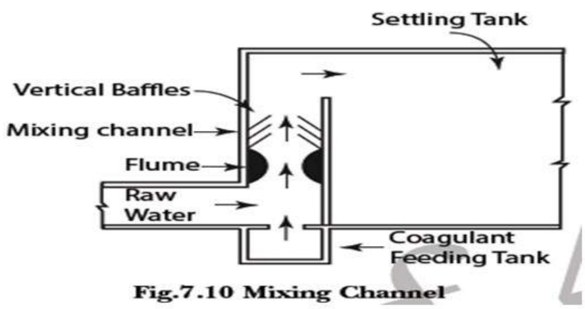


Fig.7.10 Mixing Channel

4. Hydraulic Jump Method

- Flume is provided with the channel in which the coagulant and the raw water flow.
- On passing through the flume, hydraulic jump is created which causes thorough mixing of the coagulant and the raw water.

5. Compressed Air

- Water is fed with coagulant in the mixing basin in this method.
- The compressed air is diffused from the bottom of the mixing basin which rises through the water leads to mixing of the coagulant with the water

3. Mechanical Flocculators

- Water is taken from the mixing basin to flocculators for flocculation.
- In a flocculator,slow stirring of water is brought about to permit the build up and agglomeration of the floc particles.
- Mechanical flocculators are provided with paddles for stirring of water. Thus, these are also known as paddle flocculators.
- Depending upon the direction of flow of water in the tanks the mechanical flocculators may be classified as
  (i)longitudinal flow flocculators
  (ii)vertical flow flocculators.
- The design criteria for these flocculators are as follows:
- Velocity of flow in the flocculator: 0.2 to 0.8 m/minute; normally 0.4 m/minute.
- Detention period : 20 to 60 minutes; normally 30 minutes
- Depth of tank: 2 to 4.5 m.
- Total area of paddle: 10 to 25% of the cross-sectional area of the tank.
- Outlet flow velocity to settling tank: 0.15 to 0.25 m/s (to prevent settling or breaking of flocs).

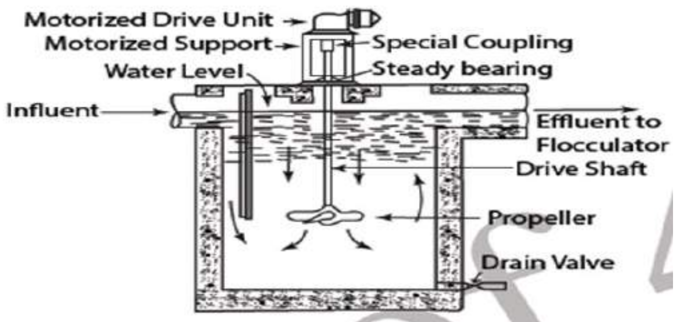


Fig. 7.11 Mechanical Flocculators

4. Sedimentation tank

- Function,design and other details are same as that we studied of plain sedimentation tank.

Design criteria

1. Mixing basin with baffle wall

- Velocity of flow in channel between the baffles is 0.15 to 0.45 m/s
- Detention time 20-50 min
- Distance between the baffles (x) should not be less than 45cm
- The clear opening between the end of each baffle and the tank wall (y) should be kept 1.5 times the distances between the baffle (x)
- The floor of channel should slope towards the outlet
- For around the baffles, depth should not less than 1m.
- The width of over and under baffles is obtained by dividing the cross-sectional area of each channel by the spacing of the baffles.
- The effective depth (effective depth of flow) is kept 2 to 3 times the distance between the baffles.

2. Mixing basin with mechanical device
    - The impeller speed kept between 100 to120 rpm
    - Detention period 0.5 to 2 minute
    - Power required for flash mixer 2-5 KW/m^3per minute
3. Flocculator

- Paddle rotation 2-3rpm

- Detention period 20-60 minute (normally 30 minute)
- The distances between the paddles and the wall or the floor of the tank 15-30cm

4. Sedimentation tank
    - Detention period 2-4 minute
    - Surface loading or overflow rate 24-30$m^3/d/m^2$

<u>Combined coagulation cum sedimentation tank</u>

- Flocculation tank combined with sedimentation tank
- A plain floc chamber without any mechanical devices is provided before the water entering the sedimentation tank.
- Detention period for floc chamber is kept at 15 – 40 minute and that for settling chamber at about 2-4 hours
- The depth in the floc chamber is kept about half that in the settling chamber
- Depth of settling tank is about 3-6m
- The tank is cleaned at intervals of 6months

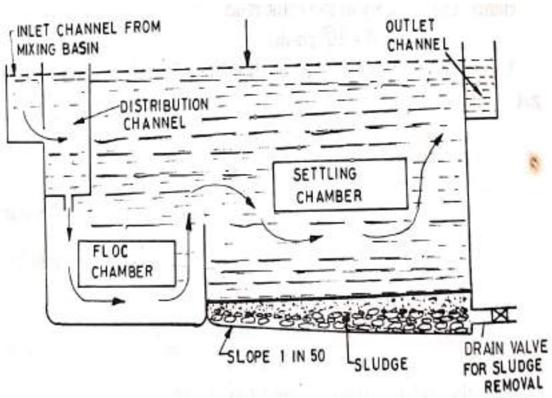


Fig. 9.24. Coagulation-Sedimentation tank.

JAR TEST

- To determine the optimum coagulant dosage.
- It is the amount of coagulant in the jar,that produces good floc with least dosage.
- The optimum dose of coagulant is determined in the laboratory by the jar test taking alum as the coagulant.

- The jar test apparatus consist of the rotary device known as multiple stirrers with paddles, motor to drive those stirrers and beakers with the capacity of about 1000ml.
- An equal volume of water is fed in all the six beakers provided on which the jar test is to be performed.
- The stirrers are then lowered so that they are immersed in the water.
- The dosage of alum with varying concentration as 5,10,15,20,25,30 mg/L are added in the different beakers
- And the paddles are rotated at the speed of 100rpm for 1 to 2 minutes which causes thorough mixing of coagulant with water.
- The speed is then lowered to 20rpm in order to form a good floc.
- The floc are allowed to settled down and residual turbidity of each jar is determined.
- The dosage of alum corresponding to lowest residual turbidity is defined as the optimum dosage.

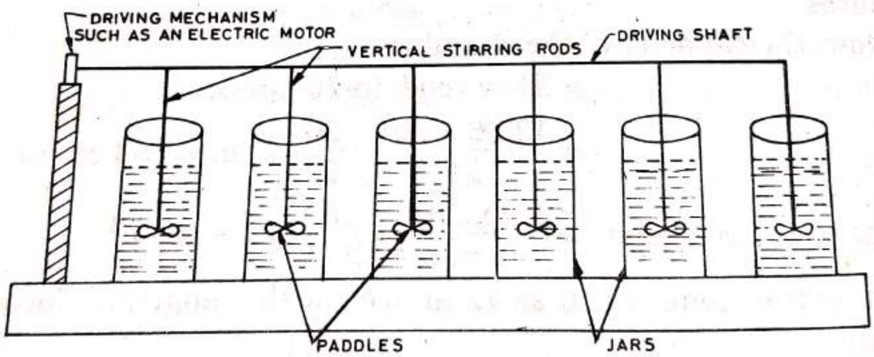


Fig. 9.26. Apparatus for jar test for determining approximate optimum coagulant dosage.

<u>Production of sludge</u>

- Suspended fine particles and precipitates that settle down-sludge
- It should be periodically removed and disposed safely
- Quantity of sludge has to be estimated for deciding depth of sludge zone and periodicity of its removal
- In 100gm of sludge only 2gm of solids and remaining 98 gm is water
- Alum generate sludge equal to 0.24 times its own mass

- Other chemicals like clay, carbon, polymers etc produce sludge equal to the amount of the Suspended produced= (suspended solids removed +0.24 times alum dose +chemicals added to raw water)

Dewatering and Disposal of sludge

- Sludge produced in water plant in
  - ✓ Clariflocculator
  - ✓ Filters
- In past, this sludge discharge in to rivers, result in huge pollution
- Lagoons: artificial and natural excavations or ditches for dewatering, thickening and temporary storage.
- Popular, acceptable and economical methods.
- Sand drying bed: for dewatering and temporary storage of wet sludge using filter bed of sand and gravel
- Gravity thickeners: To reduce volume of sludge
  - ✓ Using deeper settling tank and coagulant application
- High speed centrifuge: Advanced method for dewatering and drying the sludge
- Pressure filter: large scale process for dewatering
- Vaccum fliter: for dewatering and processing of the sludge

Q4. Design a coagulation cum sedimentation tank with the continuous flow for a population of 60,000 persons with an daily per capita demand of 120 litres. Make suitable assumptions?

OR

Design a clariflocculator to treat 7.2MLD water. Assume suitable data.

Solution:- Design of settling tank

Average daily consumption = population * per capita demand

$$= 60{,}000*120 = 7.2*10^6 L$$

Assuming

Maximum daily demend as 1.8 times average daily demand

Maximum daily demand = $1.8*7.2*10^6 = 12.96*10^6$L

Assume detention period of 4 hour

Quantity of water to be treated for detention period = $\frac{12.96*10^6}{24}*4 = 2.16*10^6 = 2160\ m^3$

Capacity of tank = 2160 m^3

Assume an overflow rate of 1000 litres/hr/m^2

That is $\frac{Q}{B*L}$ = 1000

Discharge (Q) = $\frac{12.96*10^6}{24} = 540*10^3$l/hr

Plan area BL = $\frac{\text{Q}}{\text{Overflow rate}} = \frac{540*10^3}{1000} = 540m^2$

Using width of tank = 12m, we get

Length of tank = $\frac{540}{12}$ = 45m

Depth of tank = $\frac{\text{capacity}}{\text{B*L}} = \frac{2160}{540}$ = 4m

Here we use a tank of 45m*12m*4m. providing 0.5m freeboard and also provide extra depth for sludge storage of 0.5m at the starting end and $4.5+\frac{45}{50}$ = 5.4m (using 1 in 50 slope) at downstream end.

<u>Design of floc chamber:-</u>

Effective depth of floc chamber = half the depth of sedimentation tank near the floc chamber

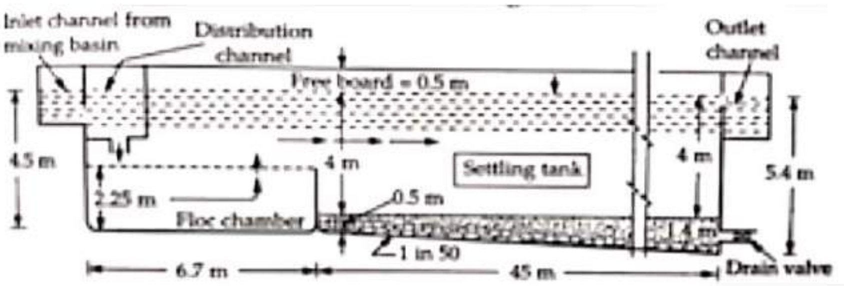
$$= \frac{4.5}{2} = 2.25m$$

Assume detention period of 20 minutes in floc chamber

Capacity of floc chamber = $\frac{12.96*10^6}{24}*\frac{20}{50} = 180m^3$

Plan area = $\frac{\text{capacity}}{\text{depth}} = \frac{180}{2.25} = 80m^2$

Using the same width as 12m, we get the length of floc chamber = $\frac{80}{12}$ = 6.7m



Q5. Find the diameter of the particle with specific gravity 1.2 removed in a tank having a surface area of 250m^2 treating 10MLd of water at 21c

Ans: Q = 10MLd = $10*10^6$litre/day = $10*10^6*10^{-3}m^3$/day $= \frac{(10*10^6)*10^{-3}}{24}$ m^3/hour

Overflow rate $= \frac{Q}{B*L} = \frac{(10*10^6)*10^{-3}}{250*24} = 1.66\ m^3/m^2hour$

$V_s = \frac{1.66}{1*60*60}$ m/Sec

$V_s = \frac{1.66*100}{1*60*60}$ cm/Sec = 0.046 cm/Sec

Applying stoke's law, $V_s = 418\ (S_s-1)\ d^2(\frac{3*T+70}{100})$

$V_s = 418\ (1.2-1)\ d^2(\frac{3*21+7}{100})$

V_s = 0.46 mm/Sec

$d^2 = \frac{0.46*100}{418*0.2*133}$ = 0.0041 mm

d = 0.064 mm

4). b. May - 2019 (10 marks)

Q. Design a continuous flow rectangular sedimentation tank for a population of 20,000 persons with an average per capita demand of 120 litres per day. Assume detention period of 6 hours.

Average daily demand = population x per capita demand

$= 20{,}000 \times 120 = 2.4 \times 10^6$ litres

Maximum daily demand = 1.8 x Average daily demand

$= 1.8 \times 2.4 \times 10^6 = 4.32 \times 10^6$ litres

Detention period = 6 hours.

∴ Quantity of water to be treated in 6 hours $= \frac{4.32 \times 10^6}{24} \times 6$

$= 1.08 \times 10^6$ litres $= 1.08 \times 10^3 \, m^3$

Hence capacity of tank $= 1.08 \times 10^3 \, m^3$.

Assume velocity of flow to be maintained through the tank.

$= 20$ cm /minute $= 0.2$ m/minute

The length of tank required = velocity of flow x Detention period

$= 0.2 \times (6 \times 60) = 72m$.

Cross section Area of the tank required $= \frac{\text{capacity of the tank}}{\text{length of the tank}}$

$= \frac{1.08 \times 10^3}{72} = 15m^2$

Assume the water depth in the tank as $4m^2$, the width of tank required $= \frac{15}{4} = 3.75$ say 4m.

using free board of 0.5m, the overall depth.

$= 0.5 + 4 = 4.5m$.

Hence rectangular sedimentation tank with an overall size of 72m x 4m 4.5m can be used.

MODULE-4

Filtration – types of filters- working and design of rapid and slow sand filters. Loss of head in filters, pressure filters

FILTRATION OF WATER

- Screening and sedimentation removes a large percentage of the suspended solids and organic matter present in raw water.
- But the resultant water will not be pure, and may contain some very fine suspended particles and bacteria present in it.
- To remove the remaining impurities, the water is filtered through the beds of fine granular material such as sands etc.
- The process of passing the water through beds of granular materials (called filters) is known as filtration.
- Filtration may help in removing colour,odour, turbidity, and pathogenic bacteria from water.

THEORY OF FILTRATION

The filters purify the water under four different processes. These actions are summarised below.

i) Mechanical straining

- The suspended particles present in water, and which are of bigger size than the size of the voids in the sand layers of the filter, cannot pass through these voids and get arrested in them. The resultant water will, therefore, be free from them.
- Most of the particles are removed upper sand layers.
- The arrested particles including the coagulated flocs forms a mat on the top of the bed, which further helps in straining out the impurities

ii) Flocculation and sedimentation

- It has been found that the filters are able to remove even particles of size smaller than the size of the voids present in the filter.

- This fact may be explained by assuming that the void spaces act like tiny coagulation-sedimentation tanks.
- The colloidal matter in void is a gelationous mass which attract other fine particles and settle down and get removed.

iii) Biological metabolism

- Certain micro-organisms and bacteria are generally present in the voids of the filters.
- They consume the impurities as their food and convert into harmless compound (biological metabolism)
- These harmless compound form a layer called dirty skin
- It help in absorbing and staining out impurities

iv) Electrolytic Charges

- The purifying action of filter can also be explained by the theory of ionisation.
- According to this theory, a filter helps in purifying the water by changing the chemical characteristics of water.
- This may be explained by the fact that the sand grains of the filter media and the impurities in water carry electrical charges of opposite nature.
- When these oppositely charged particles and impurities come in contact with each other, there by changing the character of the water and making it purer.
- After a certain interval, the electric charges of sand grains get exhausted and have to be restored by cleaning the filter.

FILTER MATERIALS

- Sand, either fine or course, is generally used as filter media. The layers of sand may be supported on gravel.

  Sand-filter media:-

- Should be free from dirt and impurities
- Should be uniform in nature and size

- Should be hard and resistant
- It permit filtered water to move freely to under-drains and wash water to move uniformly upward.
- Effective size of sand (D_{10})
    - ✓ 0.2-0.4mm(slow sand filters)
    - ✓ 0.35-0.55mm(rapid sand filters)
- Uniformity coefficient of sand is the ratio of sieve size in mm through which 60% of the sample of sand by weight will pass to the effective size of sand.

$$\therefore \text{Uniformity coefficient} = \frac{D_{60}}{D_{10}}$$

- Uniformity coefficient (Cu)
    - ✓ 1.8-2.5mm(slow sand filters)
    - ✓ 1.3-1.7mm(rapid sand filters)

Gravel-Supporting media:-

- It should be hard, durable, free from impurities.
- Use different sized gravels, arranged in 3-4 layers of each 15-20cm thick.
- Coarsest size (20-60mm) – placed in the bottom
- Finest size(3-6mm)-placed at the top

Other material-Antherafilt

- Use instead of sand as filter media
- Antherafilt- production from anthracite and is a type of coal stone that burn without smoke and flames
- Cheaper and give high rate of filtration.

CLASSIFICATION OF FILTERS

- The filters are classified based on rate of filtration in two categories

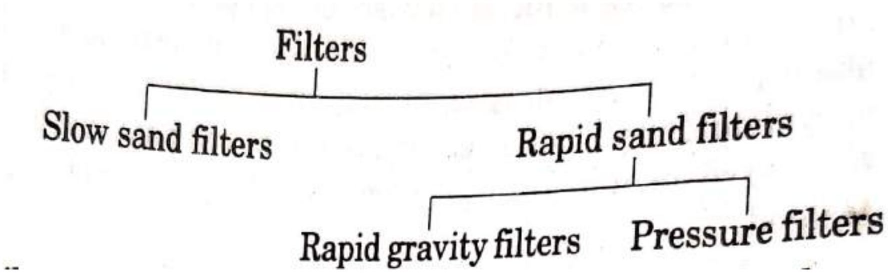
    i. Slow sand filter

ii. Rapid sand filters

- The rapid sand filter further classified in to

a) Gravity type rapid filter

b) Pressure type rapid filter



- On the basis of gravity and pressure the filters may be classified as;

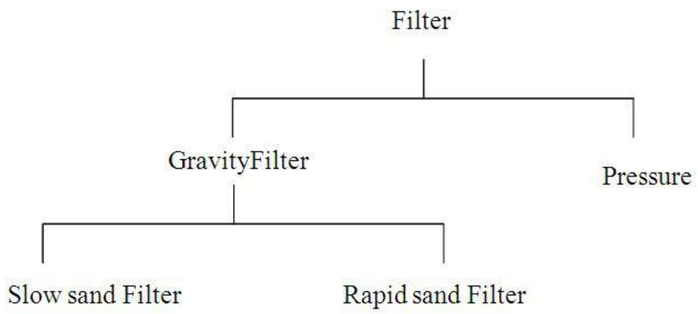


Fig.8.1 Classification of filters

- Combining above two classifications we will study the following three types of filters.

i. Slow sand filter

ii. Rapid sand filter

iii. Pressure filter

SLOW SAND FILTER

- It normally utilize effluents from the plain sedimentation tanks.
- The theory of slow sand filter is based on the principle that if water is allowed to percolate slowly through the filtering media, then the biological, chemical and physical characteristics of water are improved considerably.
- And it permits sufficient time for those improvements. That's why; the water is allowed to enter the filter bed slowly by suitable inlet arrangement.

- As the filtration takes much time, it is not suitable for large scale. It is suitable for drinking water only for small towns.

Construction of slow sand filter

- A slow sand filter consists of the following parts:

  i.Enclosure tank

  ii.Filter Media or Sand

  iii.Base material

  iv.Under drainage system

  v) inlet and outlet

  vi).Appurtenance

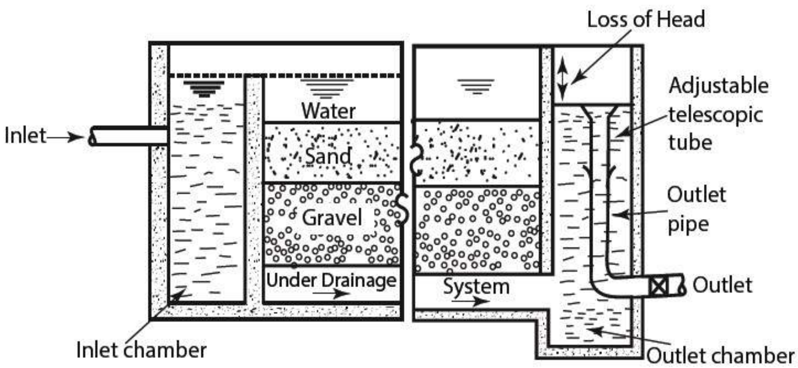


Fig. 8.2 Slow sand filter

i) Enclosure tank

- It consists of an open water-tight rectangular tank, made of masonry or concrete.
- Bed slope is kept at about 1 in 100 towards the central drain. The depth of tank may vary from 2.5 to 3.5m.
- The plan area of the tank may vary from 100 to 2000 m^2.

ii) Filter Media or Sand

- The filtering media consists of sand layers about 90 to110cm in depth, and placed over a gravel support.
- The coarsest layer should be placed near the bottom, and finest towards the top.
- The effective size of sand varies from 0.20 to 0.40mm and uniformity coefficient of sand is about 1.8 to 2.5.
- The finer the sand, the better will be the efficiency of filter regarding removal of bacteria

iii) Base material

- The base material is gravel, and it supports sand. It consists of 30 to 75cm thick gravels of different sizes, placed in layers.
- The size of gravel in the top-most layer is generally kept 3 to 6mm
- The size of gravel in the intermediate layers is generally kept 20 to 40mm and 6 to 20mm (when two intermediate layers are used)
- The size of gravel in the bottom-most layer is generally kept 40 to 65mm

iv).Under drainage system

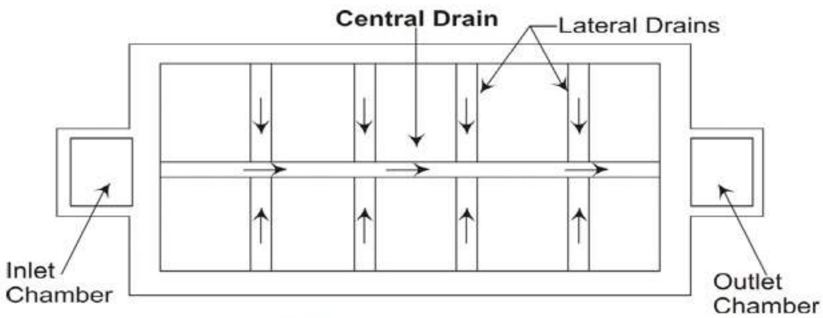


Fig. 8.3 Under drainage system

- The under drainage system consists of a central drain and lateral drains.
- The laterals are open jointed pipe drains or some other kind of porous drains placed 3 to 5m apart and sloping towards a central drain.

- The laterals collect the filtered water and discharge it into the main drain, which leads the water to the filtered water well

v) Inlet and outlet arrangement

- Inlet chamber is constructed for admitting the effluent from plain sedimentation tank without disturbing the sand layer of the filter and to distribute it uniformly over the filter bed.
- A filter water well is also constructed on the other side in order to collect the filtered water coming out from the under–drain.
- In order to maintain constant discharge through the filter, an adjustable telescopic tube is generally used.
- Inlet and outlet are generally governed by automatic valves.

vi)Appurtenance

- Besides these arrangements, certain other appurtenances are provided for the efficient functioning of these filters.
- Vertical air pipe passing through layer of sand is for proper functioning of filtering layers.
- Devices used for measuring and controlling the 'loss of head' to be installed
- The loss of head caused by the resistance offered by the sand grains to the flow through it,is usually called filter head, or filtering head.
- It is the difference of water levels between the filter tank and the filtered water well
- For a freshly cleaned filter unit, the resistance offered is less and therefore then filter head is usually small, say 10 to 15cm.
- But goes on increasing as the filter layer get clogged, filter unit must be put out of service and be cleaned.

Operation

- The treated water from the sedimentation tank is allowed to enter the inlet chamber and get distributed uniformly over the filter bed.
- The filter is filled with water to a depth of 1-1.5m above the surface of sand.

- The water percolates through the filter media and gets purified during the process of filtration.
- The water is passed through the layer at a rate of 100-150 lph/m^2 which is same as the rate of feeding
- The water now enters the gravel layers and comes out as the filtered water.
- It gets collected in the laterals through the opens joints, which finally discharge into the filtered water well, from where it can be taken to the storage tanks for supplies.
- The rate of discharge or the rate of filtration is kept constant by arrangement like of a telescopic tube.
- It may also be noted that the water entering the slow sand filter should not be treated by coagulants.
- The depth of water on the filter should neither be too large nor too small. It generally kept equal to the depth of the filter sand
- The loss of head is also called filter head or filtering head is generally limited to maximum value of about 0.7 to 1.2m
- But goes on increasing as the filter layer get clogged, filter unit must be put out of service and be cleaned.
- At that time the filter requires cleaning. For the purpose of cleaning, the layer of sand is scrapped to a depth of about 25mm and replaced by clean sand before the filter is stored again for service.

Cleaning of slow sand filters

- Cleaning is done by scrapping and removing the 1.5 to 3 cm of top sands layers.
- The top surface is finally raked, roughened, cleaned and washed with good water.
- The amount of wash water required is generally small, say 0.2 to 0.6 per cent of the total water filtered.
- Cleaning is repeated as often as necessary until the sand depth is reduced to 40 cm .Then more sand is added
- A lot of manual labour is required in cleaning.
- After cleaning, the filter is again used and raw water is admitted into it.

- But the effluent that will be obtained in the beginning will not be pure and are not used for about 24 to 36 hours until the formation of a film of arrested impurities around the sand grains (i.e.the formation of schmutzdecke)
- Since the filtering action of slow sand filters depends largely upon the formation of this film, the effluent obtained in the beginning,when such a film is absent ,shall not be pure.
- The interval between the two successive cleanings depends mainly on the nature of impurities present in the water and also on the size of the filtering sand used in the filter
- The interval normally ranges between one to three months.

Advantages of slow sand filter

1. It can remove turbidity to the extent of 50 to 60 ppm

2. It can remove colour to the extent of 25 percent

3. It can remove bacteria to the extent of about 95 percent.

Disadvantages of slow sand filter

1. Slow rate of filtration

2. Large surface area required, hence costly.

3. Removal of colour and turbidity is less.

Q1:-Design a slow sand filter from following data.

Population to be served = 50,000 persons

Per capita demand = 150 ltrs/head/day

Rate of filtration = 180 ltrs/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 out of six will be kept as stand by.

Solution :- Assume Max.demand as 1.8 times Avg.daily demand

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

Average daily consumption = population * per capita demand

$= 50,000 * 150 = 7.5*10^6$ L/day

Maximum daily demand = $1.8*7.5*10^6 = 13.5*10^6$ L/day

Rate of filtration per day = 180*24 L/sq.m/day

Total surface area of filters required = Max.daily demand / Rate of filtration per day

$$= \frac{13.5*10^6}{180*24} = 3.125*10^3 \text{sq.m} = 3125 \text{sq.m}$$

Now six units are to be used. Out of them, one is to kept as stand by and hence only 5 units should provide the necessary area of filter required.

So area of each filter unit = $\frac{\text{total area required}}{5}$

$$= \frac{3125}{5} = 625 \text{ sq.m}$$

Now, L is the length and B is the width of each unit

Then assume L=2B

$$L*B = A$$

$$2B*B = 625$$

$$2B^2 = 625$$

$$B^2 = 312.5$$

$$B = 17.7m = 18m$$

$$L = 2(18) = 36 \text{ m}$$

Hence use six filter units with one as stand-by. Each unit of size 36m*18m, arranged in series with 3 units on either side.

<u>RAPID SAND FILTER</u>

- It is observed that the rate of infiltration is more in coarse sand than that in fine sand.
- So, the theory of rapid sand filter is based on the principle of increasing the rate of filtration by providing coarse sand as filter media.
- The filtration head is also increased to increase the pressure head and the rate of filtration.
- We have seen in slow sand filter that the rate of filtration is very low and it requires more space for installation.

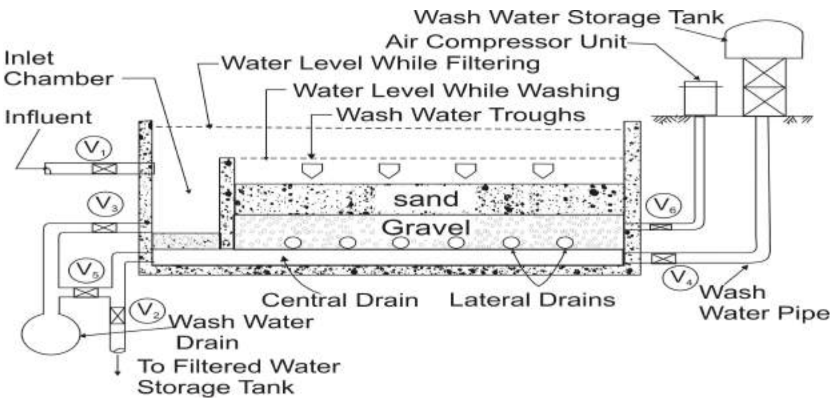
- To overcome these difficulties, the fine sand in slow sand filter is replaced by coarse sand to achieve greater percolation and to reduce surface area.
- Used for large town
- Use large sized particle
- High rate of filtration= 3000 – 6000 liter/hour/m2 (3-6m3/hr/m2)
- Water from coagulation sedimentation tank is used
- The filtered water is treated with disinfectants
- Less efficient in removing bacteria and turbidity
- Removes bacteria only up to 80-90%
- Remaining bacteria is removed by disinfection methods
- Turbidity removes only up to 35-40 mg/L

❖ Rapid sand filters are of two types.

Gravity type

Pressure type

✓ The gravity type rapid sand filters are most commonly used in water supply projects.



Essential features of rapid sand filters

Enclosure tank

Under drainage system

Base material

Filter media or sand

Appurtenance

Enclosure tank:

- It is a open rectangular tank.
- It consists of a water tight tank constructed with brick masonry.
- The inside surface is plastered with rich cement mortar (1:3) with water proof compound and finished with neat polish.
- The depth varies from 2.5 to 3.5m.
- The surface area depends on the volume of water to be filtered. However, the surface area varies from 10 to 80 m^2 for each unit.

Filter Media of Sand:

- The coarse sand of effective size of 0.35 to 0.55mm and uniformity coefficient 1.3 to 1.7 is generally used as the filtering media.
- The depth of sand layer varies from 60 to 90cm.
- Coarser particles at the bottom and finer particle at the top.

Base Materials:

- Clean gravels of different size are used as base materials.
- It consist of 60-90cm thick gravels of different sizes.
- These gravels are placed on the under drainage system in five to six layers, each layer being 10-15cm thick.
- The bottom layer is made of bigger size gravels of 20 to 40mm.
- Two intermediate layers are provided, between 12 to 20 mm and 6 to 12mm.
- Top most layer between 3 to 6mm.

Under Drainage System:

- The under drainage system consists of central drain and perforated lateral drains.

- The lateral drains are connected to the central drain from both sides and they are placed at a distance of 30cm centre to centre.
- Generally, G.I. pipes of required diameter are used in under drainage system.
- It receive and collect filtered water
- It allow back washing for cleaning
- It consist of manifold and lateral drains.
    - ✓ Manifold or main drain
        - 40cm diameter main drain running along the center
    - ✓ Lateral drain
        - 10cm diameter laterals spaced at 10-30cm apart.
    - ✓ Laterals may be:-
        1. Perforated pipes system
        2. Pipe and strainer system

1. Perforated pipes system

- Lateral drains with holes at the bottom.
- 6-13 mm diameter holes at 30^0 with vertical
- Spacing of holes – 7.5-20cm

2. Pipe and strainer system

- Lateral drain with strainer pipe having perforated cap.
- Strainer pipe at 15cm apart on lateral pipe

Appurtenance:

- In addition to the above following appurtenance are also provided

Wash water trough

- To collect dirty wash water comes out of filter after cleaning it.
- It can be square ,v-shaped or semi-circular in section
- It is made of concrete , steel or fiber glass
- Spacing = 1.1-2 m apart

- Discharge through wash water trough is given by

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

b= width in m and y= water depth in m

Air compressor

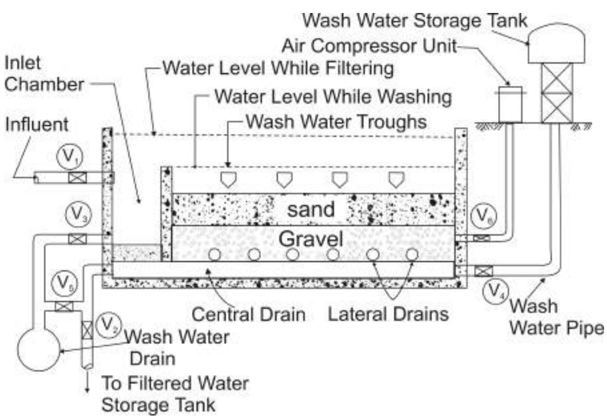
- For agitating filter during back washing
- It should be able to provide compressor air at a high rate

Rate controller

- Commonly used venture rate controller
- To obtain uniform rate of filtration

Working of Rapid Sand Filter

- The water from the coagulation tank enters the inlet chamber through the inlet pipe.
- In normal working condition, the valves V1 and V2 are kept open and other valves are kept closed.
- Then the water uniformly spreads over the filter media.
- The filtered water is collected in the central drain through the filter media. Finally, the water is taken to the storage tank.
- When loss of head exceeds some limit, then a negative head is formed.
- At this time the function of filter stopped. It requires washing to resume normal working condition.



Cleaning of rapid sand Filter

- Cleaning of rapid sand filter is done by back washing and surface washing

Back washing

- Wash water and compressed air is sent back upward through the filter bed.
- This will agitate the sand particles and remove impurities.
- This dirty water after cleaning is collected in wash water troughs
- After cleaning, the filter is again set to work. But the filtered water cannot be used for sometimes as it contains some impurities.
- The entire process of back washing takes 15 minutes.
- Amount of water for back washing = 2-5 % of total filtered water.
- Rapid sand filter have to be washed every 24 -48 hours
- Rate of washing = 15 to 90 cm/minutes
- Pressure of washing= 40 kN/m^2
- During washing period the valves V1 and V2 are kept closed.
- The valves V4 and V6 are opened. The wash water and compressed air are forced through the under drainage system.
- After some time, the valve V6 is closed and valve V3 is opened so that the dirty water can be removed through the wash water drain.
- When washing is over, the valves V3 and V4 are closed. But V1 and V5 are kept open for some time.
- Finally, the valve V5 is closed, and V1remains open. Now V2 is opened to start the normal working.

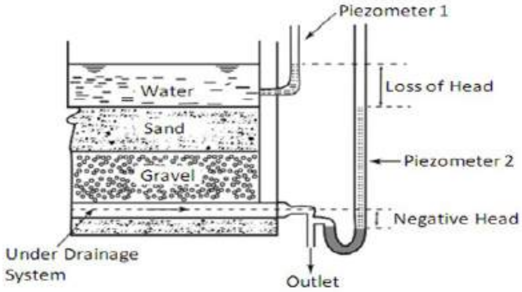
Surface wash

- Clean filtered water applied to the sand bed from above using nozzle.
- It scour the particles and clean the surface.

TROUBLES IN RAPID SAND FILTER

- The following are the common troubles in rapid sand filter:

1. Loss of Head and Negative Head



Loss of Head:

- The water has to face a frictional resistance when it passes through the filtering media. So, it loses some of its head.
- If piezometer-1 is inserted in the water above the sand bed and piezometer-2 is fitted with outlet pipe as shown in above Figure, the two piezometers will show a difference of water level.
- That difference is known as *loss of head*. Initially, the loss of head is small.
- But it increases gradually due to the deposition of suspended matters over the sand bed.
- Ultimately, a stage may come, when the

Negative Head:

- When the water level in the piezometer-2 goes below the centre line of under drainage, then the distance between the centre line and the water level in piezometer-2 is known as *Negative head*.

1.Air Binding

- When head loss due to clogging,negative pressure develops.
- This results in releasing of dissolved air in water and cause formation of air bubbles
- These bubbles sick to the sand grains and affect the working the washing of filter badly
- It decrease the rate of filtration.

Remedial measures

- Avoid situation of head loss
- Control growth of algae
- Prevent water getting warmed

2.Formation of mud Balls

- Mud from atmosphere accumulate on sand surface
- During inadequate washing these mud sick down into the filter bed
- Mud sicks to sand grains and form mud ball
- Their size go on increasing and affect filtration and back washing

Remedial measures

- Brake mud ball mechanically
- Brake mud ball by water nozzle
- Use compressed air to scour mud ball
- Apply caustic soda
- Replace filter bed

3.Cracking of Filter

- If the filter is not washed in proper time, then it is found that the sediments on the sand bed form cracks on the edges of the filter media.
- This is known as cracking of filter. This trouble is eliminated by breaking the mud balls and washing the filter properly.

<u>Design</u>

<u>Design of filter tank</u>

- Area of filter bed = $\frac{discharge}{rate\ of\ filtration}$
- Length of filter tank = 1.5B-2B
- Where B is the width of filter tank

- Rate of filtration=3000-6000 liter/hour/m^2

Design of under drainage system

- Manifold and perforated pipes
- Total cross-sectional area of perforation= 0.2% of total filter area
- Cross-sectional area of each lateral = 2-4 times of area of perforation
- Cross-sectional area of Manifold = 2 times that of laterals
- Max permissible velocity in manifold to provide wash water = 1.8 – 2.4 m/s

Design of under drainage system

- Spacing = 1.1 - 2 m
- No of unit = $\frac{widt\ \ of\ filter}{spacing\ of\ trou}$
- Discharge through wash water trough is given by $Q=1.376by^{3/2}$
- Rate of washing = 15-90 cm/min
- Width of trough is assumed to be equal to depth in trough
- Wash water discharge = rate of washing * area of filter

Q2: Design a rapid sand filter unit for 4 ML/day of supply with all its principal components. Assume suitable data. (1)

Solution:-

Design of filter unit

Assume 4% of filter water is used for back washing & half hour per day is for the washing.

Water required per day = 4 million Litre

considering the 4% for back washing:

The total filtered water required $= 4 + \left(4 \times \frac{4}{100}\right)$

$= 4.16$ ML/day

considering backwashing time as half hour.

Discharge per hour $= \frac{4.16 \times 10^6}{23.5} = 0.177 \times 10^6$ L/hr (24hr − 0.5hr)

Now, Assume Rate of filtration = 5000 l/hr/m² (3000–6000)

Rate of filtration $= \frac{Q}{BL}$

$5000 = \frac{177.02 \times 10^3}{B \times L}$

$\therefore BL = 35.404 \, m^2$ → Area of a filter unit or a set

thus, area of one filter $= \frac{35.404}{2}$

$= 17.702 \, m^2$

We know that, $L = 1.5B$

$A = L \times B$

$= 1.5B \times B = 1.5B^2$

$\therefore B = 3.4 \, m$

$\Rightarrow L = 1.5 \times 3.4 = 5.15 \approx 5.2 \, m$

b) Design of underdrainage s/m:-

Provide manifold & perforation pipe as under-drainage s/m.

(i) Total area of perforations in all laterals

$= 0.2\%$ of total area of filter.

$= \frac{0.2}{100} \times (5.2 \times 3.4) = \frac{0.2}{100} \times 17.68 = 0.03536\,m^2$.

(ii) Area of each lateral = 2 (Area of perforations)

$= 2 \times 0.03536 = 0.07072\,m^2$.

(iii) Area of manifold / main pipe = 2 × (Area of laterals)

$= 2 \times 0.07072 = 0.141\,m^2$.

(iv) Diameter of manifold $A = \pi/4\, d^2$.

$0.141 = \frac{\pi}{4} \times d^2$

$d = 0.42\,m$

$\approx 45\,cm$.

Assume spacing of laterals as 15 cm.

No: of Laterals = Length of filter ÷ Spacing of lateral

$= \frac{5.2}{15 \times 10^{-2}} = 34.67 \approx 35$ no.s.

Hence use 70 laterals on either side of each unit

Now, length of Lateral = $\frac{\text{Width of filter} - \text{Dia of Manifold}}{2}$

$= \frac{3.4 - 0.45}{2} = 1.475\,m$.

Adopt Dia: of perforations as 13mm.

∴ No: of perforations = $\frac{\text{Total area of perforations}}{\text{Area of one perforation}}$

$= \frac{0.03536}{\frac{\pi}{4}(13 \times 10^{-3})^2} = 266.4 \approx 267$.

Thus, No: of perforations in each lateral.

$$= \frac{267}{70} = 3.8 \simeq 4$$

So, Area of perforation in each lateral

$$= 4 \times \frac{\pi}{4} \times (13 \times 10^{-3})^2 = 5.309 \times 10^{-4} m^2$$

Area of each lateral $= 2 \times 5.309 \times 10^{-4} = 1.06 \times 10^{-3} m^2$.

Area of lateral $= \pi/4 \, d^2$.

$$1.06 \times 10^{-3} = \frac{\pi}{4} d^2$$

$$d = 0.0368 m \simeq 3.7 cm$$

Hence use 70 laterals, each of 3.7cm diameter at 15 cm spacing each having 4 perforations of 13cm dia with 45cm dia manifold.

i) Design of wash water trough.

Use spacing as 1.1m.

$$\therefore \text{No: of trough} = \frac{\text{Width of filter}}{\text{Spacing}} = \frac{3.4}{1.1} = 3.09 \simeq 4 \text{ nos}$$

Wash water discharge = Rate of washing x Area of filter.

Rate of washing = 60 cm per minute = 1 cm/s = 0.01 m/s.

$$= 0.01 \times 17.68 = 0.177 \, m^3/s$$

$$\text{Discharge in each trough} = \frac{\text{Total wash water Discharge}}{\text{No: of trough}}$$

$$= \frac{0.177}{4} = 0.044 \, m^3/s$$

Discharge through washwater trough, $Q = 1.376 \, b y^{3/2}$

Assume width of trough = depth of trough.

so, $b = y$

$\Rightarrow Q = 1.376 \times b \times b^{3/2}$

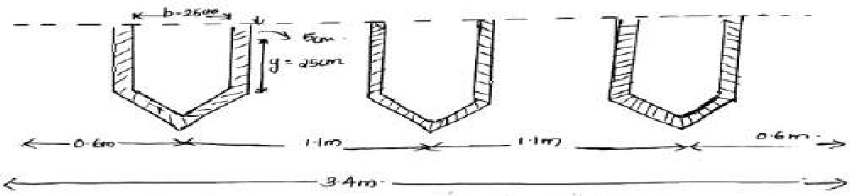
$\frac{0.044}{1.376} = b^{5/2}$

$b^{5/2} = 0.032$

$b = 0.25 = 25cm$

Keeping 5cm free board, adopt $y = 25 + 5 = 30cm$.

Hence use 4 No: of wash water troughs of size 25cm × 30cm



COMPARISON BETWEEN SLOW SAND FILTER AND RAPID SAND FILTER

Table shows the comparison between slow sand filter and rapid sand filter:-

S. 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.	Loss of head	15 cm initial to 100 cm final	30 cm initial to 3 m final
3.	Size of bed	Requires large area	Requires small area
4.	Congulation	Not required	Essential
5.	Filter-media of sand	Effective size : 0.2 to 0.35 mm C_u : 2 to 3 Depth : 105 cm, reduced to not less than 30 cm by scrapping	Effective size : 0.35 to 0.6 mm C_u : 1.2 to 1.7 Depth : 75 cm; not reduced by washing
6.	Base material of gravel	Size : 3 to 65 mm Depth : 30 to 75 cm	Size : 3 to 40 mm Depth : 60 to 90 cm
7.	Underdrainage system	Split tile laterals discharging into tile or concrete main drain ; or perforated pipe laterals	Perforated laterals with mains or wheeler system, or Leopald system or Wagner system for underdrainage
8.	Method of cleaning	Scrapping of top layer to 15 mm to 25 mm	Agitation and back-washing with or without compressed air
9	Amount of washwater	0.2 to 0.6% of water filtered	2 to 4% water filtered
10.	Period of cleaning	1 to 2 months	2 to 3 days
11.	Penetration of suspended matter	Superficial	Deep
12.	Supplementary treatment of water	Chlorination	Chlorination
13.	Efficiency	Very efficient in the removal of bacteria but less efficient in the removal of colour and turbidity	Less efficient in removal of bacteria, more efficient in the removal of colour and turbidity
14.	Economy	High initial cost	Cheap and economical
15.	Flexibility	Not flexible in meeting variations in demand	Quite flexible for reasonable fluctuations in demand
16.	Skilled supervision	Not essential	Essential
17.	Depreciation cost	Relatively low	Relatively high

PRESSURE FILTER

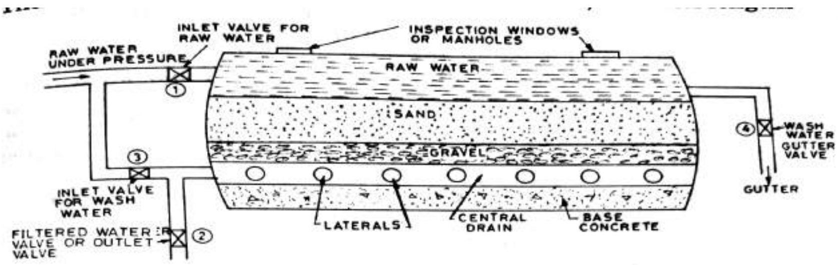


Fig. 9.37. (*a*) **Horizontal pressure filter.**

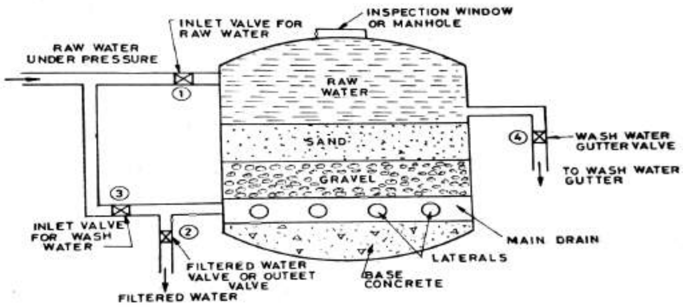


Fig. 9.37. (*b*) **Vertical pressure filter.**

- Pressure filters is a type of rapid gravity filters placed in closed vessels, and through which water to be treated is passed under pressure.
- Since water is forced through such filters at a pressure greater than the atmospheric pressure, it is necessary that these filters are located in air tight vessels.
- The raw water is pumped into the vessels by means of pumps,the pressure so developed may normally vary between 30 to 70 metre head of water.
- The filter is operated similar to a gravity type rapid filter except that the coagulant water is usually applied directly to the filter without mixing, flocculation or conditioning,
- It may be horizontal or vertical type.

Construction

- The filter vessel may be installed either in a horizontal or in a vertical position, depending upon which, they may be classified as horizontal pressure filters or vertical pressure filters.

- Typical cross- section of vertical pressure filter is shown in above figure.
- Steel cylinders are used as pressure vessel and may be riveted or welded.
- Diameter varies from 1.5 to 3m and length varies from 3.5 to 8 m.
- Inspection windows are provided at top for inspection purpose.

Working and operation of pressure filters

- The pressure filter is operated like an ordinary rapid gravity filter except that the raw coagulated water is neither flocculated nor sedimented before it enters the filter.
- The flocculation takes place inside the pressure filter itself.
- Under normal working conditions, the coagulated water under pressure enters the filter vessel through the inlet valve1, and the filtered water comes out of the outlet valve 2.
- Hence, under this condition, only these two valves are kept open and all other valves are kept closed.
- The commonly used coagulant is alum and is kept in a pressure container connected to the influent line to the filter.
- Little time is thus available for this coagulant to get mixed properly
- The cleaning of the filter may be carried out by back washing as is done in a normal rapid gravity filter.
- The compressed air may also be used, if designed, in order to agitate the sand gains.
- For cleaning the inlet and outlet valves (valves 1 and 2) are closed and the wash water valve 3 and wash water gutter valve 4 are opened.
- After the completion of cleaning, these valves may be closed, and raw supplies restore
- However, the filtered supplies should not be collected for a little time and wasted through valve 4, as is done in a rapid gravity filter.

Rate of filtration of pressure filter

- The pressure filter can yield filtered water at rates much higher i.e,2 to 5 times than what can be obtained from rapid gravity filters.
- Their rate filtration normally ranges between 6000 to 15000 litres per hour per.sq.m of filter area.

Efficiency and suitability of pressure filter

- The pressure filters are less efficient than the rapid gravity filters in removing bacteria and turbidities.
- The quality of effluent is poorer and they are generally not used for public supplies.
- They may installed for colonies of few houses, individual industries ,private estates, swimming pools

Advantages of pressure filters

The advantages of pressure filters over rapid gravity filters are given below.

1. Pressure filters are compact and can be handled easily
2. It requires lesser space and lesser filtering material for treating the same quantity of water.
3. Sedimentation and coagulation tanks are avoided.
4. They are more flexible, as the rate of filtration can be changed by changing the pumping pressure.
5. It is economical for treating smaller quantities of water.
6. 6. Since the water coming out of the filter possesses sufficient residual head, the pumping of the filtered water is not required.

Disadvantages of pressure filters

The disadvantages of pressure filters over rapid gravity filters are given below.

1. They are less efficient in removing bacteria and turbidities, and hence, the quantity of the filtered effluents is poorer.

2. They are costlier, particularly for treating large scale municipal supplies.

3. Since filtration takes place in a closed tank, proper inspection and quality control is not possible.

4. Since these filters are operated under pressure, the normal tendency is to pump the water at higher rates, and thus obtaining still poorer quality of effluents.

MODULE-5

Disinfection of water- methods, chlorination – types, factors affecting-cholrine demands. miscellaneous treatment – ion exchange, lime-soda process, electro dialysis- colour, taste and odour removal-adsorption-aeration-fluoridation-deflouridation

DISINFECTION OF WATER

- When water comes out of filter plants, it may contain bacteria and other micro-organisms, Some of which may be pathogenic.
- It is therefore necessary to disinfect water to kill bacteria and other micro-organisms, and thus prevent water borne diseases.
- The chemicals used for killing these bacteria are known as disinfectants, and the process is known as disinfection or sterilization

MINOR METHODS OF DISINFECTION

Following are the minor methods of disinfection.

1. Boiling method
2. Excess lime treatment
3. Iodine and bromine treatment
4. Ozone treatment
5. Potassium Permanganate
6. Silver treatment
7. Treatment with ultra-violet rays

1. **Boiling method**:

- When water is boiled above a certain temperature, bacteria are killed.
- The boiling of water is the most effective method of disinfection.
- But to boil water on a large scale is impossible.
- Moreover, it can only kill the existing germs but cannot take care of the future possible contaminations.
- This method is hence not at all used for disinfecting public supplies.

2. **Excess lime treatment:**

- The treatment of lime is given to water for the removal of dissolved salts.
- But it was found that excess lime is added to water, it will also work in addition as a disinfecting material.
- The action of excess lime is based on the fact that lime increases pH value of water.
- The extreme alkalinity (acidity) is detrimental to bacteria. Hence, when pH value of water is about 9.50 or so, bacteria can be removed to the extent of 99.93 or 100 percent.
- But when this treatment is adopted for disinfection, the excess lime is to be removed by any suitable method of re-carbonation after disinfection.
- It was used old days, nowadays this method is not used.

3. Iodine and bromine treatment:

- When water is treated with iodine or bromine, it is disinfected.
- The dosage of iodine or bromine is about 8ppm, and the contact period with water is about 5 minutes.
- These available in the forms of pills.
- The use of iodine and bromine is limited to small water supplies such as swimming pools, private plants etc.

4. Ozone treatment:

- It is an excellent disinfectants.
- Ozone gas is an unstable allotropic forms of oxygen, with each molecule containing three oxygen atoms.
- But when a high-tension electric current is passed through a stream of air in a closed chamber tri-atomic molecules of oxygen are formed as shown by the following equation.

$$O_2 + O = O_3$$

- Such oxygen is known as ozone.
- The third atom is very loosely bounded and the ozone easily breaks down into oxygen and releases nascent oxygen which is very powerful in killing bacteria.
- The equipment called Ozonizer is used in the ozone treatment.

Disadvantages

- It is very costly.
- Ozone needs electricity for its manufacture and hence it can be used only when electricity is available easily and cheaply.
- No residuals can be maintained because it is highly unstable, and thus it use does not ensure safety against possible future contaminations.
- It is less efficient than chlorine in killing bacteria

Advantages

- Ozone being unstable, nothing remains in water, by the time it reaches the distribution system
- Ozone removes the colour, taste and odour from water in addition to removing the bacteria from it
- The ozonised water becomes tasty and pleasant unlike the chlorinated water which becomes bitter to tongue.

5. Potassium permanganate:

- This disinfectant works as a powerful oxidising agent and is found to be effective in killing cholera bacteria.
- However, it is less effective for other water-disease producing organisms.
- The water treated with this disinfectant produces a dark brown coating on porcelain vessels and this coating is difficult to remove.

6. Silver treatment:

- It has been found that silver has the property of disinfecting water.
- The metallic silver is placed as filter media and water while passing through such a filter absorbs some portion of silver which disinfects the water.
- The dosage of silver varies from 0.05 to 0.1 mg/l and the period of contact is about 15 min to 3 hrs.

7. Treatment with ultra-violet rays:

- The ultra-violet ray offers an effective method for sterilization of water, since the light is effective in killing both the active bacteria as well as spores.
- U-V rays are generated by machines consisting of mercury-vapor lamp enclosed in a quartz globe.
- This treatment does not develop any taste or colour in the water and there is no danger of over dose.
- It is suitable for water supply installation of private institutions, swimming pools etc.

CHLORINATION

- In this treatment for disinfection, the chlorine is used as disinfecting material.
- For treatment on large scale, chlorination is invariably used as treatment for disinfection.
- This method is cheap, reliable, easy to handle, easily measurable.
- It is capable of providing residual disinfecting effects for long periods, thus affording complete protection against future recontamination of water in the distribution system.
- Its only disadvantage is that when used in greater amounts, it imparts bitter and bad taste to the water, which is not accepted by certain consumers.

Advantages of chlorination

1. It accomplishes greater bacterial purification in minutes.
2. It is cheap and avoids, wholly or in part, the necessity for raw water storage.
3. It provides extra security against water-borne diseases.
4. The processes is economical and cheap.
5. It is harmless to human beings.
6. It is reliable and effective.
7. Residual chlorine can be maintained in water.ad taste to the water, which is not accepted by certain consumers.

CHLORINE DEMAND

- Chlorine and its compounds are consumed by a variety of organic and inorganic materials present in water due to its oxidising power before disinfection is achieved.

- The amount of chlorine consumed in the oxidation of these impurities, before any disinfection is achieved, is known as chlorine demand of water.
- After the chlorine demand is fulfilled, chlorine will appear as free available residual chlorine.
- The free available residual chlorine will then serve as disinfectant to kill to the pathogens present in water.
- Thus the difference between the amount of chlorine added to the water and the residual chlorine is called chlorine demand.
- Generally, most waters are satisfactorily disinfected if the free available residual chlorine is about 0.2 mg/litre at the end of 10 minutes contact period.

FORMS OF APPLICATION OF CHLORINE

Chlorine may be applied to water in one of the following form:

1. As free chlorine
2. As chloramines
3. As bleaching powder
4. As chlorine dioxide.

(1) Free chlorine

- Free chlorine is available in gaseous or liqiud form.
- Chlorine is stored in cylinder, 80% of the contents being in liquid form and the rest in gaseous form.
- The chlorine is fed to a water-supply by means of a device called chlorinator.
- It regulates the flow of gas from the chlorine container at the desired rate.

Advantages

- It can be stored for long time.
- It is very powerful and effective disinfectant
- It is available cheaply
- Initial coast of chlorine plant is low.

- There is no sludge formation.
- Skilled supervision is not necessary.

(2) Chloramines

- Chlorine is not stable in water.
- Hence it is sometimes mixed with ammonia to form stable compounds called chloramines.
- In this treatment, ammonia as NH_3 is added to the water just before the chlorine is applied.
- The usual proportions are 1 part of ammonia to 4.5 parts of chlorine by weight.
- These have adequately good disinfecting properties and are specially useful for disinfecting swimming pools.

Advantages:

- It is more effective than chlorine alone.
- It prevents bad taste and odour, particularly those due to phenols.
- The quantity of chlorine required becomes less, especially if organic matter is present in large amounts.
- Water treated with this causes less irritation to skin, nose and eyes.
- There is no danger of over dose.

(3) Bleaching powder

- Bleaching powder is a compound of chlorine and contains about 30% chlorine.
- When bleaching powder is used as disinfectant, it is also called hypo-chlorination. Bleaching powder is available in the form of powder.
- It is unstable and loses chlorine when exposed to atmosphere.
- Hence it has to be stored carefully. It is therefore used only on small installations or under emergency conditions.
- Hypochlorite is applied to water as a solution by means of hypochlorite feeding apparatus.

Advantages

- They are available in small packets in powder form.
- Their chlorine content does not decrease with storage.
- They can be applied to water in dry condition or as solution.

(4) Chlorine dioxide.

- Chlorine dioxide is a very effective and powerful disinfectant.
- The chlorine dioxide gas is costly and very unstable and has to be used immediately after its production.
- For these reasons, it is generally not used for treating ordinary public supplies.
- However, because of its stronger disinfecting powers, it may be used for treating waters containing larger disinfecting powers, it may be used for treating waters containing larger amounts of organic impurities.

TYPES OF CHLORINATION

Depending upon the stage at which chlorine is applied to water chlorination can be of the following types.

(1) Plain chlorination

(2) Pre-chlorination

(3) Post-chlorination

(4) Double chlorination

(5) Break point chlorination

(6) Super chlorination

(7) Dechlorination

(1) Plain Chlorination

- This term is used to indicate that only chlorine is added to water and no other treatment has been given to raw water.
- Water from deep wells, lakes, reservoirs etc., is comparatively clear with turbidity less than 30ppm.

- In such cases no treatment such as sedimentation, coagulation etc. is necessary.
- When no other treatment except chlorination is given before supplying water to consumers, it is called plain chlorination.
- It removes bacteria, colour and organic matter.
- Dosage of chlorine is 0.5 mg/L or more.

(2) Pre-Chlorination

- Pre-chlorination is the process of applying chlorine to the water before filtration or before sedimentation.
- It helps in reducing the loads on the filters.
- It also reduces the taste, odour, algae and other organisms.
- The normal doses required are as high as 5 to 10mg/L.
- Pre chlorination is followed by post chlorination.

Advantages

1. It reduces the bacterial load on filters.

2. It helps in maintaining longer filter runs.

3. It controls the algae and planktons in basins and filters.

5. It eliminates tastes and odour.

(3) Post-chlorination

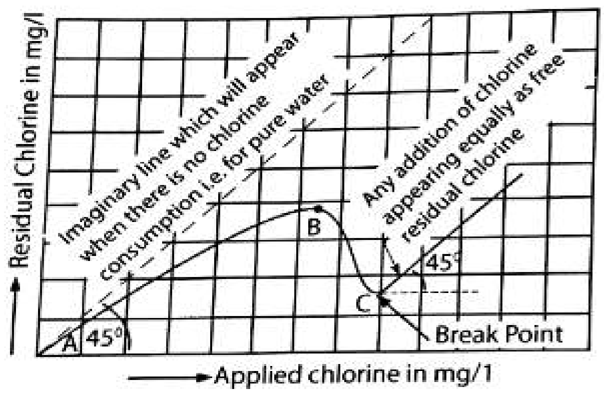
- Post chlorination or sometimes simply called chlorination is the normal standard process of applying chlorine in the end, when all other treatments have been completed.
- While treating normal public supplies, the post chlorination is adopted after filtration and before the water enters the distribution system.
- The dose of the chlorine should be so adjusted that the residual chlorine is about 0.1 to 0.2 ppm before water enters the distribution system.

(4) Double chlorination

- The term double chlorination is used to indicate that the water has been chlorinated twice.
- The pre-chlorination and post-chlorination are generally used in double chlorination. Post chlorination, however, is generally always used.
- The pre-chlorination is used when the waters is highly turbid and contaminated.

(5) Break point chlorination

- It is the addition of chlorine after break point.
- After break point ,any addition of chlorine appear as free residual chlorine
- When chlorine is added to water, initially it react with ammonia and form chloramines.
- Break point is the point at which chlorine consumed all the ammonia and further addition of chlorine remains as free chlorine.



(6) Super chlorination

- Super-chlorination is the application of chlorine beyond the stage of break point.
- It is the amount of excessive amount chlorine (5-15mg/L) so as to produce a residue of 1-2mg/L.
- It is used under special cases like highly polluted water or during epidemics.

(7) De chlorination

- It is the process of removing excess chlorine from water before distribution to the consumers to avoid chlorine tastes.
- This is generally required when super-chlorination has been practiced.
- Extra chlorine is removed from water such that a residue of 0.2 mg/L do remain even after de chloridation.
- De chlorination is done by adding some de chloridation agents. Some de chloridating agents are
  - ✓ $S0_2$
  - ✓ Activated carbon
  - ✓ Sodium thiosulphate
  - ✓ Sodium sulphite
  - ✓ Sodium bisulphate
  - ✓ Ammonia

9.7 FACTORS AFFECTING CHLORINATION

The destruction of pathogens by chlorination is dependent upon the following factors.

(i) Turbidity

(ii) Presence of metallic compounds

(iii) Ammonia compounds

(iv) pH of water

(v) Temperature

(vi) Time of contact

(vii) Number and concentration of bacteria.

1. Turbidity: The effect of turbidity in water is to make it difficult to obtain free residual chlorine. The penetration of chlorine and destruction of bacteria in turbid water is very uncertain. Due to this reason, chlorination is preferred after filtration.

2. Presence of metallic compounds: If metallic compounds like iron and manganese are present in water, utilizes large amounts of chlorine to convert these into their higher stages of oxidation which are insoluble in water. Hence it is essential to remove iron and manganese, to make chlorination is more effective.

3. Ammonia compounds: The presence of ammonia with or without organic matter may form combined available chlorine which is not so effective in killing bacteria as free available chlorine. Hence to add sufficient chlorine to react with the amount of natural ammonia present and a further dose of chlorine enough to create an excess of free chlorine for speedy disinfection.

4. pH of water: Increasing pH reduces effectiveness of chlorine. The effective sterilising compound, hypochlorous acid, is formed in greater quantities at low pH than at high pH values.

5. Temperature of water: Reduction in the temperature of water results in substantial decrease in the killing power of both free and combined chlorine. In order to have 100% bactericidal activity, the requirement of residual chlorine increases with decrease in temperature and increase in pH.

6. Time of contact: The bactericidal activity of chlorination is not instantaneous. The percentage kill of bacteria and viruses depends upon the time of contact between the chlorine and the pathogens, before the water is supplied to the consumers. The contact time required for disinfection by free chlorine acting in clear water is 20 minutes, but it is 60 minutes for combined chlorine, such as chloramines etc.

7. Number and concentration of bacteria: At a given pH value and temperature, the greater the numbers of bacteria, the longer will be the time required to reduce them below a given value.

MISCELLANEOUS WATER TREATMENT METHODS

- Besides the normal treatment process, such as coagulation, sedimentation, filtration and disinfection.
- Certain other special treatments are sometimes required in order to remove the special minerals, tastes, odours, colours etc. from water.
- The following are the some of the miscellaneous treatment methods for making the water better in every way.

1. Removal of colour, odour and taste

2. Fluoridation and . Defluoridation

3 Desalination (removal of salt)

4. Water softening

REMOVAL OF COLOUR, ODOUR AND TASTE

- The presence of organic matter, algae, dissolved hydrogen Sulphide and contamination due to industrial wastes containing phenol, excessive chlorine, etc. and dissolved iron and manganese salts impart **colour, odour and taste to the water.**
- **Following are some** important water treatment methods employed for *removing color, taste and odor***.**
- Following methods are adopted.

  1. Aeration

  2. Absorption

3. Treatment with copper sulphate
4. Treatment with oxidizing agents.

i) Aeration

- Aeration is the process of bringing water in intimate contact with air.
- During the process, water absorbs oxygen from the air and removes ($CO_2$and H_2S).
- Up to certain extent bacteria is also killed. However, it can remove CO_2 up to 10% only.
- The aeration can be done by the following methods

a. By using Air diffusion

- In this method, compressed air is bubbled through the water, so as to thoroughly mix it with water.
- Perforated pipes are, therefore, installed at the bottom of the aeration tanks, and the compressed air is blown through them.
- The compressed air is thus bubbled up from the bottom of the tank.
- During its upward movement through the water body, it gets thoroughly mixed up with the water contained in the tank, thereby completing the aeration process.

b. By using Trickling Beds

- Allow water to trickle down through perforated trays arranged vertically in series. During the downward movement air get mixed up.

c. 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.
- Carbon di-oxide gas is thus considerably removed in this method.
- Carbon dioxide removed up to 90 %.

d. By using cascades

- In this method, the water is made to fall through a certain height over a series of steps with a fall about 0.15 to 0.3m in each step.

- So that it comes in contact with air, and thus the colour, odour and taste of water are removed.
- It removes 60-70% of carbon dioxide.

(ii) Absorption

- It is the treatment with activated carbon, which attracts and absorbs impurities gases, fine solids etc.
- Activated carbon is added to the water before filtration.
- The dosage of activated carbon is 5-20mg/l.
- Activated carbon is obtained by charring wood or saw dust at 500°Cin a closed vessel, thereby hydrocarbons, which usually interfere with the absorption of organic matters, are expelled.
- It is available in granular or powdered from.
- Activated carbon is most widely used for the removal of tastes and odors from the public water supplies, because it has excellent properties of attracting gases, finely divided solid particles and phenol type impurities.

(iv) Water Treatments with Copper Sulphate

- Copper sulphate ($CuSO_4 7H_2O$) solution usually applied with dose of 0.5 to 0.65 mg/liter to the treated water, just before it is allowed for distribution in the mains.
- It can also be added in the lakes or reservoirs. Cropper sulphate helps in removing odors, tastes and colors from the water.
- Its main advantage is that it checks the growth of algae, even before production and also kills some bacteria.

(v) By Oxidation

- The Oxidation of organic matters is done by adding chlorine, potassium permanganate, ozone, etc. to water as oxidizing agents.
- Generally the excess chlorine is added beyond the break point for oxidizing the organic matters.

FLUORIDATION

- Fluoridation is the addition of fluorine to the water.
- Fluorine content in water should be 1 to 1.5 mg/l
- The deficiency of fluorine cause dental carries decay of teeth etc.
- Fluoridation is done by adding sodium fluoride (NaF) and sodium silicofluride (Na_2SiF_6) by chemical fed equipment.

DEFLUORIDATION

- Removal of excess fluorine in water
- Extra fluorine more than 1.5 mg/l cause dental problems
- Dental fluorosis is the condition of discoloured, blackend, mottled, or chalky white teeth.
- Skeletal fluorosis leads to severe and permanent bone and joint deformations.
- Following are the principal methods of defluoridation:

Calcium phosphates.

- Bone has great affinity for fluorides and can be used in the filter for removal of fluorides.
- The bone is calcinated at 400^{o}C to 600^{o}C for 10 minutes followed by mineral acid treatment.
- It is then pulverized to pass 40 to 60 meshes and is used in the filter bed.
- The filter is regenerated with alkali and acid. One cubic meter of bone can treat 1 million litres of water containing 3.5 ppm. of fluoride.

Bone charcoal.

- It is essentially tri-calcium phosphate and carbon, and has been used successfully for the removal of fluorides.

Synthetic tri-calcium phosphate.

- It can be prepared from milk of lime and phosphoric acid when the reaction is carefully controlled.
- This material has been used in contact filters for removal of fluorides.
- The regeneration can be done by 1% caustic soda followed by a dilute hydro-chloric acid or carbon dioxide wash to neutralise the excess alkali.

Fluorx.

- Fluorx is a special mixture of tri-calcium phosphate and hydroxyapatite.
- It is used as filter medium. Fluorex can beregenerated by washing with 1.5% solution of caustic soda.
- It can be next rinsed with twice its volume of water and the excess soda can be neutralised with the solution of carbon dioxide at 0.15% strength.

Ion-exchanger.

- There are a number of ion-exchanger materials which can be used for removal of fluorides.
- Fluorides in water can be removed by successive passage through beds of cation-exchanger.
- Alum treated cation exchange resin from Avaram bark can be used as an effective material for removing fluorides from water.

Synthetic Tri-calcium phosphate.

- It can be prepared from milk of lime and phosphoric acid when the reaction is carefully controlled.
- This material has been used in contact filters for removal of fluorides.
- The regeneration can be done by 1% caustic soda followed by a dilute hydro-chloric acid or carbon dioxide wash to neutralise the excess alkali.

Nalgonda Technique.

- In India and particularly in rural areas, ground water containing excess fluoride is treatd by Nalgondatechnique.
- Nalgonda technique uses aluminium salt (alum) for removing fluoride.
- The raw water is firstly mixed with adequate amount of lime (CaO) or sodium carbonate (Na_2CO_3) and thoroughly mixed.
- Alum solution is then added, and water is stirred slowly for about 10 minutes, and allowed to settle for nearly one hour.
- The precipitated sludge is discarded, and the clear supernatant containing permissible amount of fluoride is withdrawn for use.

Activate carbon.

- Removal of fluoride from water has also been effected by treatment with activated carbon, at pH 3.0.
- No removal takes place at pH 8 or above.
- The carbon when used as a contact bed can be regenerated with the weak acid and alkaline solution.

DESALINATION

- Only about 0.5% of the earth's water is potable.
- The remaining 97% is ocean water and 2.5% is brakish water, both of which are impotable because of their dissolved salt content.
- The process of removing this salt from water is known as desalination, and the resultant water which is free from salt is known as fresh water.
- Following are common methods used for desalination:

1. Distillation.
2. Reverse osmosis
3. Electro dialysis.

4. Freezing.

5. Solar evaporation.

WATER SOFTENING

- **Water is said to be 'hard' when it contains relatively large amount of carbonates, bicarbonates, sulphates and chlorides of calcium and magnesium dissolved in it.**
- **These materials react with soap, causing a precipitation which appears as a scum or curd on the water surface. all be removed by anion exchange.**
- Hardness is of two types: (i) temporary hardness, and (ii) permanent hardness.
- The temporary hardness is the one which is deposited when water is boiled, and is usually known as carbonate hardness.
- The permanent hardness is also known as non-carbonate hardness, and is mainly due to the presence of sulphates, chlorides and nitrates of calcium and magnesium.
- ***Removal of temporary hardness:*** Temporary hardness or bicarbonate hardness can be removed by boiling and by adding lime. Method of boiling has practical limitations on large scale.

Removal of permanent hardness:

Permanent hardness can be removed by one of the following methods.

1. Lime-soda process.

2. Zeolite process/Base exchange process.

3. Ion exchange process.

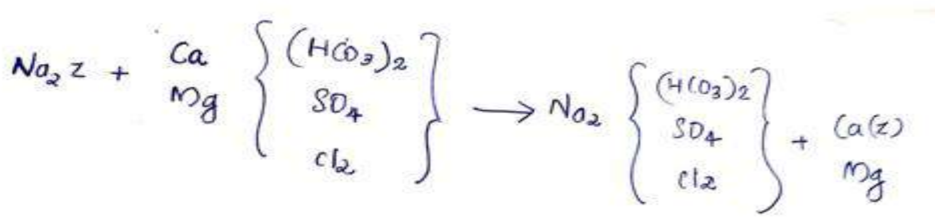
1. Lime-soda process.

- Lime soda process is one of the water softener systems. In this system calcium hydroxide (lime, $Ca(OH)_2$) and soda (Na_2CO_3)ash are used as reagents.
- By this process soluble magnesium and calcium salts are removed as calcium carbonate and magnesium hydroxide precipitated.

- Finally the formed precicpitate sedimented out. We obtain soft water. lime removes carbonate hardness of calcium and magnesium.
- Soda removes non-carbonate hardness of calcium.

<u>2.Zeolite process/Base exchange process</u>

- It is called cation exchange process.
- The zeolite is hydrated silicate of sodium and aluminium ($Na_2O.Al_2O.SiO_2.H_2O$).
- When zeolite is added to water sodium ion of zeolite get replaced by calcium and magnesium.



3) Deminarlisation process:-

- It is done by passing water through cation exchange and anion exchange resins.
- Initially cation exchange resin added and it exchange hydrogen with metallic ion.

$$Ca\,(HCO_3)_2 + H_2R \rightarrow CaR + 2H_2O + 2CO_2$$

- Non-carbonate hardness produce HCI and H_2SO_4.This acids are removed by adding anion exchange resins, which exchange hydroxide ion.

$$ROH + HCI \rightarrow RCI + H_2O$$

<u>3. Ion exchange process.</u>

- Ion exchange water treatment system is one of the most common processes and it is works on the basis on ion exchange principle.
- It removes the scale-forming calcium and magnesium and other metal ions from hard water.
- To remove these ions water are passes through ion exchange column filled with synthetic resin.

Electro Dialysis.

- Electro Dialysis (ED) is used to transport salt ions from one solution through ion-exchange membranes to another solution under the influence of applied electric potential difference.
- This is done in a configuration called an electrodialysis cell.
- Two different membranes are used- one more selective to anions and the other more selective to cations.
- Brackish water is introduced into a narrow channel, one of those walls is an anion permeable membrane, and another which is a cation-permeable membrane.
- The passage of electric current aids the diffusion of these ions, and the electric energy required is proportional to the concentration of salts in the saline water.
- The process is suitable especially for brackish waters with total concentration up to 5000mg/L.