UNIT- I

SOURCES OF WATER

Importance and Necessity for Planned water supplies

- Water is a chemical compound and may occur in a liquid form or in a solid form or in a gaseous form
- Everyone one of us knows how important and precious the water is.
- No life can exist without water since water is essential for life as air is.
- Water is absolutely essential not only for the survival of human beings, but also for animals, plants and all other living organisms.
- Further, it is necessary that the water required for their needs must be good, and it should not contain unwanted impurities or harmful chemical compounds or bacteria in it.
- Therefore, in order to ensure the availability of sufficient quantity of good quality water, it becomes almost imperative in the modern society, to plan & build suitable water supply schemes, which may provide potable water to the various sections of the community in accordance with their demands & requirements.

- The provisions of such a scheme shall ensure a

1) Constant & a reliable water supply

2) Keep the diseases away & thereby promoting better health.

3) Help in supplying water for foundations, gardens, etc.

4) Helps in maintaining better sanitation & beautification of surroundings, thereby reducing environmental pollution.

Planning and Execution of Modern Water Supply Schemes

- In planning a water supply scheme, it is essential, to first of all, search a source of water in the vicinity of the town or the city for which the scheme is to be designed.
- Sometimes, the water may be available nearby, & sometimes it may be far away.
- Further it may be an underground well, or it may be a river, stream or a lake.
- It is, therefore, necessary to seek out all the possible sources and evaluate each in terms of quantity, quality & cost.
- Suitable systems should then be designed for collecting, transporting & treating this water.
- The treated water is finally distributed to the

residents and industries depending upon their requirements, through a network of distribution system.

- The essentials elements of a public water supply scheme may, therefore consists of Intakes, & reservoirs, a water treatment plant, elevated tanks and stand pipes which provides storage, valves which controls the flow of water, sub mains & branch lines.

Water Demand:

- Whenever an engineer is given the duty to design a water supply scheme it becomes necessary to evaluate the amount of water available & the amount of water demanded by the public.
- Water demand is the amount of water required for an area or for a person against the amount of water available.

Various Types of Water Demands:

The various types of water demands, which a city may have, may be broken into the following classes

1) Domestic water demand
2) Industrial water demand

③ Institutional & Commercial water demand
④ Demand for public uses
⑤ Fire demand &
⑥ Water required to compensate losses in waste & thefts.

① Domestic water demand:

- This includes the water required in private buildings for drinking, cooking, bathing, lawn sprinkling, gardening, sanitary purposes, etc.,
- The amount of domestic consumption for a town or a city with flushing system should be taken at 200 l/h/d, although it can be reduced to 135 l/h/d.

② Industrial Water demand:

- It represents the water demand of industries, which are existing or likely to be started in future.
- This quantity will thus vary with the number & types of industries present in the city.
- It is generally taken as 50 l/c/d.

③ Institutional and Commercial Water Demand:

- The water requirements of institutions, such as hospitals, hotels, restaurants, schools & colleges, railway stations, offices, factories, etc.,

- On an average, a per capita demand of 20 l/h/d is usually considered to be enough, this demand may be as high as 50 l/h/d for highly commercialised cities.

(4) Demand for public uses:

- This includes the water required for public utility purposes, such as watering of public parks, gardening, washing & sprinkling on roads, use in public foundation, etc.,
- 10 l/h/d is usually added to this account.

(5) Fire demand:

- The high rate of water consumption during a fire considerably public water supply schemes. It is calculated based on the following formulas

a) Kuichling's Formula:

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

b) Freeman's Formula

$$Q = 1136\left[\frac{P}{10} + 10\right]$$

c) National board of Fire under Writer's Formula

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

d) Buston's Formula:

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

Where, Q = Amount of water required in l/min

P = Population in thousands.

⑥ Water Required to Compensate Losses in Thefts & Wastes:

- This includes the water lost in leakage due to bad plumbling, or damaged meters, stolen water due to unauthorized water connections & other losses & wastes.

- This amount is taken tobe as high as 15% of total consumption.

Design Period:

The future period for which a provision is made in the water supply scheme is known as design period.

It is therefore necessary to estimate this future population as accurately as possible.

The population of the region just by the end of the design period is estimated using different methods, such as:

1. Arithmetical increase method
2. Geometrical increase method
3. Increamental increase method
4. Decreasing rate method
5. Simple graphical method
6. Comparative graphical method
7. Master plan method.
8. The apportionment method
9. The logistic curve method

The Per Capita Demand:

It is the annual average amount of daily water required by one person, and includes the domestic use, industrial and commercial use, wastes, thefts, etc

It is expressed as

$$\text{Per Capita Demand} = \frac{\text{Total yearly water requirement of the city in litres}}{365 \times \text{Design Population}}$$

For an average Indian City, the per capita demand may be taken as given in table

Use	Demand in l/h/d
i) Domestic Use	200
ii) Industrial Use	50
iii) Commercial use	20
iv) Civic or Public use	10
v) Waste & Thefts	55
Total	= 335 Per Capita Demand

Factors Affecting Per Capita Demand:

- The annual average demand for water considerably varies for different towns & cities.
- It generally ranges between 100 to 360 litres/capita/day.
- These variations in different cities or towns depend upon various factors, such as

1) Size of the city
2) Climatic Conditions
3) Habits of people
4) Industrial & Commercial Activities
5) Quality of water supplies
6) Pressure in the distribution system
7) Development of sewerage facilities
8) System of supply
9) Cost of water
10) Policy of metering & method of charging

Factors Affecting Losses and wastes

1) Water tight joints
2) Pressure in the distribution system
3) System of supply

4) Metering
5) Unauthorised Connections.

Factors Governing the design period:

1) Useful life of component structure and the chances of their becoming old & obsolete.
2) Ease and difficulty that is likely to be faced in expansions, if undertaken at future dates.
3) Amount and availability of additional investment likely to be incurred for additional provisions.
4) The rate of interest on the borrowings & the additional money invested.

Population forecasting methods:

The various methods which are generally adopted for estimating future population by engineers.

Some of these methods are used when the design period is small, and some are used when the design period is large.

① Arithmetic Increase Method:

This method is based upon the assumption that the population increases at a constant rate. i.e., the rate of change of population with time is constant.

$$P_n = [P_0 + n.\bar{x}]$$

Where, P_n = Forecasted population after n decades from the present. (ie, last known census)

P_0 = Population at present (ie, last known census]

n = No. of decades between now & future

$\bar{x}$ = Average of population increases in the known decades.

(1) The population of 5 decades from 1930 to 1970 are 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	25,000	28,000	34,000	42,000	47,000

SOLUTION:

Year	Population	Increase in Population
1930	25,000	
		3000
1940	28,000	
		6000
1950	34,000	
		8000
1960	42,000	
		5000.
1970	47,000	
Total		22,000

Average increase per decade ($\bar{x}$) $= \frac{22,000}{4}$

$= 5,500$

The future Populations $P_n = P_0 + n.\bar{x}$

∴ (a) Population after 1 decade beyond 1970

$P_{1980} = P_{1970} + 1.\bar{x}$

$= 47,000 + 1 \times 5,500$

$= 52,500.$

(b) Population after 2 decade beyond 1970

$P_{1990} = P_{1970} + 2.\bar{x}$

$= 47,000 + 2 \times 5500$

$= 58,000.$

(c) Population after 3 decade beyond 1970

$P_{2000} = P_{1970} + 3.\bar{x}$

$= 47,000 + 3 \times 5,500$

$= 63,500.$

② Geometric Increase Method

In this method, the per decade percentage increase or ~~decrease~~ percentage growth rate (r) is assumed to be constant, & the increase is compounded over the existing population every decade.

Population after 1 decade

$P_1 = P_0\left(1 + \frac{r}{100}\right)$, where r is in percent

Population after 2 decades

$$P_2 = P_0 \left(1 + \frac{r}{100}\right)^2$$

Proceeding in this way, we can write

$$P_n = P_0 \left(1 + r/100\right)^n$$

Where, P_0 = Initial Population

P_n = Future Population

r = Assumed growth rate (%)

2) Solve Problem ① using geomtric increase method.

Year ①	Population ②	Increase in Population in each decade ③	Percentage increase in population i.e., growth rate (r) = $\frac{Col(3)}{Col(2)} \times 100$ ④
1930	25,000		
		3,000	$\frac{3000}{25,000} \times 100 = 12\%$
1940	28,000		
		6000	$\frac{6000}{28,000} \times 100 = 21.43\%$
1950	34,000		
		8000	$\frac{8000}{34,000} \times 100 = 23.53\%$
1960	42,000		
		5000	$\frac{5000}{42,000} \times 100 = 11.90\%$
1970	47,000		

The geometric mean of the growth rates (r)

$= \sqrt[4]{12 \times 21.43 \times 23.53 \times 11.9}$

$= 16.38\%$ per decade

Now, assuming that the future population increases at this constant rate (16.38 %), we have

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

$$P_n = P_0 (1 + 0.1638)^n$$
$$= P_0 (1.1638)^n$$

Using n = 1, 2, 3 decades, we have

The population after 1 decade

$$P_{1980} = 47,000 (1.1638)$$
$$= 54,699.$$

The population after 2 decade

$$P_{1990} = 47,000 (1.1638)^2$$
$$= 63,658.$$

The population after 3 decade

$$P_{2000} = 47,000 (1.1638)^2$$
$$= 74,085.$$

③ Incremental Increase Method:

In this method, the per decade growth rate is not assumed to be constant but is progressively increasing or decreasing depending upon whether the average of the increamental increases in the past data is positive or negative.

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

Where P_n = Population after n decades from present

$\bar{x}$ = Average increase of population of known decades.

$\bar{y}$ = Average of incremental increases of the known decades.

3) Solve problem 1 by Increamental Increase method

Year (1)	Population (2)	Increase in Population (3)	Incremental increase (i.e., increment on the increase (4)
1930	25,000		
		3000	
1940	28,000		+ 3000
		6000	
1950	34,000		+ 2000
		8000	
1960	42,000		- 3000
		5000	
1970	47,000		
Total		22,000	+ 2000
Average per decade		$\bar{x} = \frac{-22,000}{4} = -5,500$	$\bar{y} = \frac{2200}{3} = +667$

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

Hence, $P_{1980} = 47,000 + 1 \times 5500 + \frac{1 \cdot (1+1)}{2} \cdot 667$

$= 53,167$

$P_{1990} = 47,000 + 2 \times 5,500 + \frac{2(2+1)}{2} \cdot 667$

$= 60,001$

$P_{2000} = 47,000 + 3 \times 5,500 + \frac{3(3+1)}{2} \cdot 667$

$= 67,502$

④ Decreasing Rate of growth method:

This method is applicable only in cases, where the rate of growth shows a downward trend

4) Solve example (i) by decreasing rate method.

Year	Population	Increase in Population	Percentage Increase in Population	Decrease in the percentage Increase
1930	25,000			
		3000	12%	
1940	28,000			- 9.40%
		6000	21.4 %	
1950	34,000			- 2.1%
		8000	23.5%	
1960	42,000			+ 11.6%
		5000	11.9%	
1970	47,000			
Total				-11.5 + 11.6 = 0.1%
Average Per decade				$\frac{0.1}{3}$ = 0.03% decrease

a) Expected population at the year 1980

$$= 47{,}000 + \frac{11.9 - 0.03}{100} \times 47{,}000$$

$$= 47{,}000 + \frac{11.87}{100} \times 47{,}000$$

$$= 47{,}000 + 5570$$

$$= 52{,}570.$$

b) The expected population at the end of year 1990

$$= 52{,}570 + \frac{11.87 - 0.03}{100} \times 52{,}570$$

$$= 52{,}570 + 6230$$

$$= 58{,}800$$

c) The expected population at the end of year 1990

$$= 58{,}800 + \frac{11.84 - 0.03}{100} \times 58{,}800$$

$$= 58{,}800 + \frac{11.81}{100} \times 58{,}800$$

$$= 58{,}800 + 6950$$

$$= 6{,}5750$$

5) Simple Graphical Method:

In this method, a graph is drawn from the available data, between time & population. The curve is then smoothly extended upto the desired year.

6) Comparative Graphical Method:

In this method, the cities having conditions and characteristics similar to the city whose future population is to be estimated are, first of all, selected.

It is then assumed that the city under consideration will develop, as the selected similar cities have developed in the past

7) Zoning method (or) Master Plan method

8) The ratio method (or) the Apportionment method

9) The Logistics curve method.

Sources of Water:

After estimating the water requirement for the proposed water supply scheme, the planners must go in for search of nearby water sources, which may be available for the required amount of water.

The various sources of water available on the earth can be classified as

① Surface Sources:

1) Ponds & lakes

2) Streams & rivers

3) Storage reservoirs
4) Oceans, generally not used for water supplies.

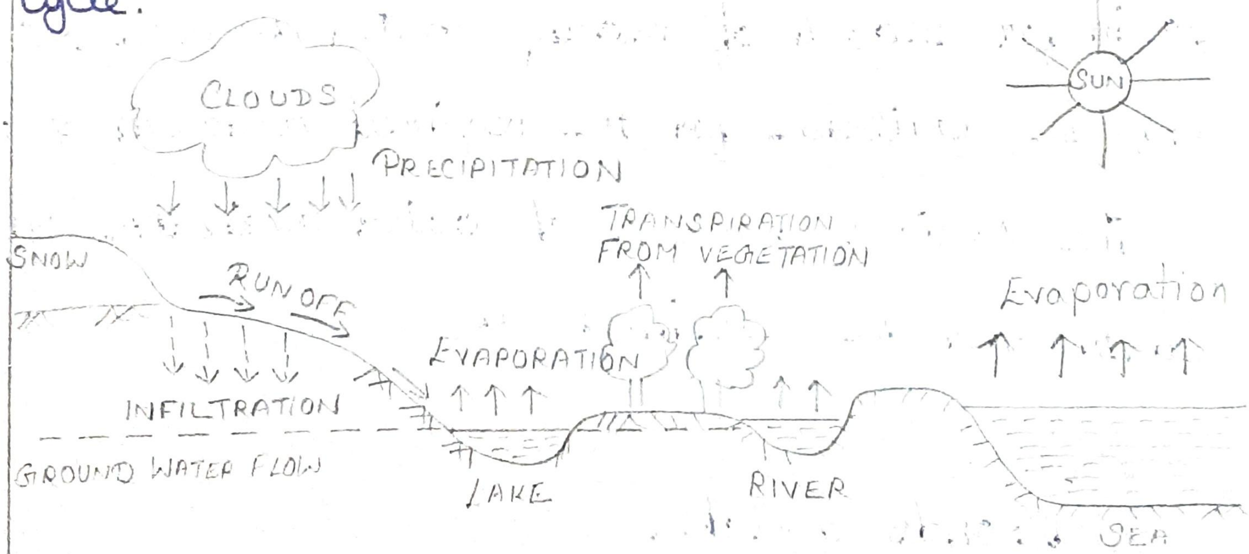
② Sub-Surface sources

1) Springs
2) Infiltration galleries
3) Infiltration wells and
4) Wells & tube wells

Hydrological Cycle:

The various earth's water-sources get their supplies from precipitation, while the precipitation in itself is the evaporation from these sources.

The precipitation and evapouration continues for ever, & thereby a balance is maintained between the two. This process is known as hydrological cycle.



Surface Sources of water supplies

Surface sources are those sources of water in which the water flows over the surface of the earth, & is thus directly available for water supplies

The important of these sources are

i) Natural Ponds & Lakes

ii) Streams & rivers &

iii) Impounding reservoirs.

① Ponds and Lakes:

A natural large sized depression formed within the surface of the earth, when gets filled up with water, is known as a pond or lake.

The quality of water in a lake is generally good and does not need purification.

Larger and older lakes provide comparitively purer water than smaller & newer lakes.

Self purification of water due to sedimentation of suspended matter, bleaching of colour, removal of bacteria, etc makes the lake's water purer & better.

In still water of lakes & ponds, the algae, weed &

and vegetable growth takes place freely, imparting bac
smells, tastes & colours to their waters

The quantity of water available from lakes is however, generally small.

It depends upon the catchment area of the lake basin, annual rainfall & geological formations.

Due to smaller quantity it is useful for only small towns & hilly areas.

2. Streams & Rivers:

- Small streams are used only for small villages.

Larger & perennial streams may, be used as source of water, by providing storage reservoirs, barrages, etc across them.

Rivers are the most important sources of water for public water supply schemes.

Rivers may be perennial or non perennial.

Perennial rivers are those in which water is available throughout the year.

The construction of a dam is generally adopted on a highly non-perennial river.

The quality of water from rivers is generally not reliable, as it contains large amounts of silt, sand and a lot of suspended matter.

The disposal of the untreated or treated sewage into the river is further liable to contaminate their waters.

Therefore it must be properly analyzed & well treated before supplying to the public.

③ Storage reservoirs:

A water supply scheme drawing water directly from a river or a stream may fail to satisfy the consumers demands during extremely low flows; while during high flows, it may again become difficult to carry out its operations due to devastating floods.

A barrier in the form of a dam may, therefore, sometimes be constructed across the river, so as to form a pool of water on the upstream side of the barrier.

This pool formed on the upstream side of the dam is known as storage reservoir.

The quality of this reservoir water is not much different from that of a lake water.

Sub surfaces or underground sources:

The water which gets stored in the ground water reservoir through infiltration, etc., is known as under ground water.

This water is generally pure, because it undergoes natural filtration during the percolation through soil pores.

These waters are less likely to be contaminated by bacteria.

Sometimes, the ground water is brought to the surface by some natural processes like springs, and sometimes these waters are tapped by artificial means by construc-ting wells, tube wells, infiltration galleries, etc.,

Factors governing the selection of a particular source of water

1) The Quantity of available water
2) The Quality of available water
3) Distance of the source of supply

4) General Topography of the Interviewing Area
5) Elevation of the source of supply.

Occurrence of Groundwater

The rainfall that percolates below the ground surface, passes through the voids of the rocks, and joins the water table.

These voids are generally inter-connected, permitting the movement of ground water.

The mode of occurance of ground water depends largely upon the type of formation, & hence upon the geology of the area.

The volume of water contained in the ground water reservoir in any localised area is dependent upon

i) the porosity & permeability of the rocks
ii) the rate at which water is added to it by infiltration
iii) the rate at which water is lost from it by evaporation, transpiration seepage to surface courses & withdrawal by man.

Geological Factors governing the occurrence of groundwater

① Porosity:

It is defined as the percentage of the voids present in the soil aggregate.

$$\text{Porosity} = \frac{\text{Total volume of voids in the soil aggregate } (V_v)}{\text{Total volume of the soil aggregate } (V)}$$

S.No	Types of rock formation	Porosity
1.	Granite, Quartzite	1.5%
2.	Slate, Shale	4%
3.	Limestone	5 to 10%
4.	Sandstone	10 to 15%
5.	Sand & Gravel	20 to 30%
6.	Only gravel	25%
7.	Only Sand	35%
8.	Clay & Soil	45%

Porosity Values of a Few Rock Formations

(2) Permeability & Transmissibility:

Permeability is defined as the ability of a rock or unconsolidated sediment, to transmit or pass water through itself.

Coefficient of Permeability:

It is defined as the rate of flow of water through a unit cross-sectional area of the water bearing material under a unit hydraulic gradient, & at a temperature of 20°c.

Various forms of underground sources

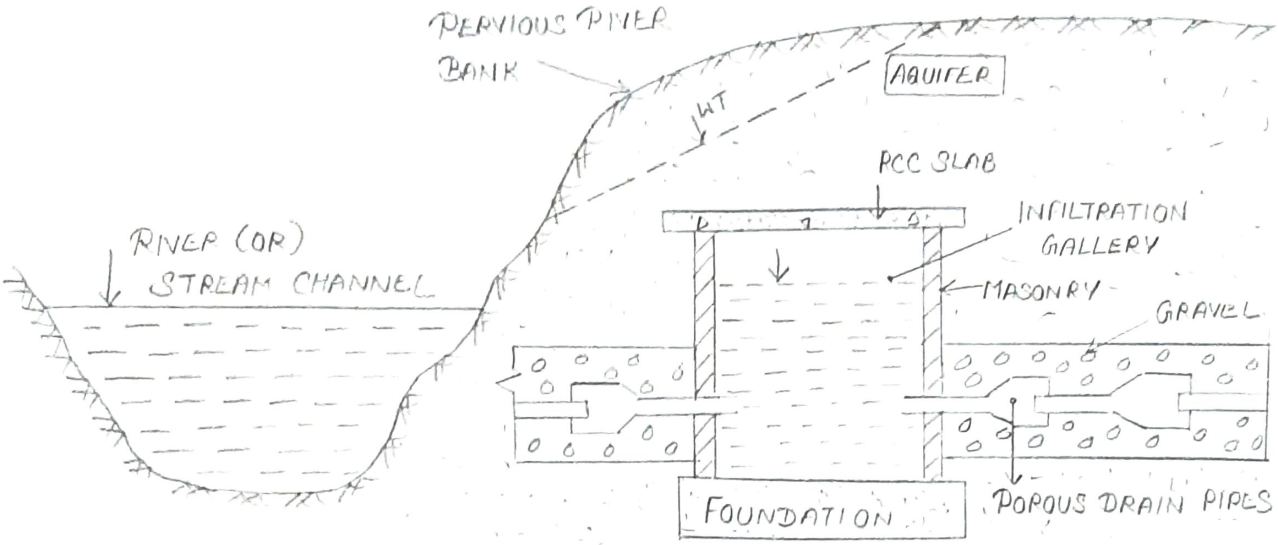
The underground water is generally available in the following forms

1) Infiltration Galleries
2) Infiltration wells
3) Springs and
4) Wells including tubewells

① Infiltration Galleries:

They are horizontal tunnels constructed at shallow depths (3 to 5 m) along the banks of rivers through the water bearing strata. They are sometimes called horizontal wells.

The tunnels are generally laid at a slope, and the water collected in them is taken to a sump well, from where it is pumped, treated & distributed to the consumers.



They have width of about 1m, depth of about 2m and length varying from 10m to as long as 100m, depending on the extent of water field.

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

Where K = Permeability coefficient of the aquifer
L = Length of gallery
R = Radius of influence
H = Static water level above bottom of gallery
h = depth of water in gallery on pumping equilibrium.

① $600 m^3/day$ of water is to be obtained from a proposed infiltration gallery, which is placed at 6m depth from sub-surface water table. The coefficient of permeability of the soil aquifer is 100m/day. Find the length of the gallery if the drawdown in the gallery on pumping is not to exceed 4m. The radius of influence may be assumed to be 100 m.

Solution:

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

Where $Q = 600 m^3/day$, $H = 6m$, $h = 6-4 = 2m$

$R = 100m$ $K = 100 m/day$.

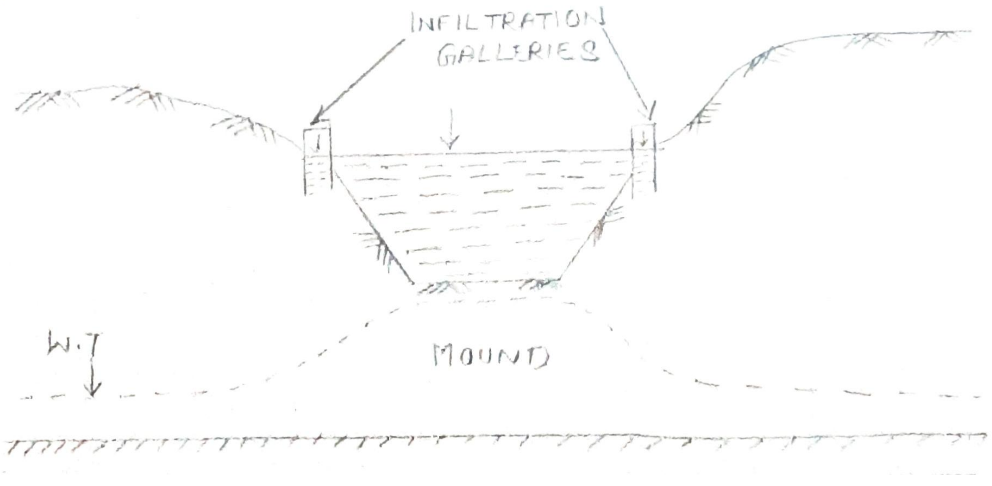
$$600 = 100 \times L \times \left(\frac{6^2 - 2^2}{2 \times 100}\right)$$

$$L = \frac{600 \times 200}{100 \times 32}$$

$L = 37.5m$

② Infiltration wells:

They are the shallow wells constructed in series along the banks of a river, in order to collect the river water seeping through their bottoms.



These wells are generally constructed of brick masonry with open joints.

They are generally opened at the bottom & covered at the top.

For inspection purposes, manholes are provided in the top cover.

③ Springs:

The natural outflow of ground water at the earth's surface is said to form a spring.

A pervious layer sandwitched between two impervious layers gives rise to a natural spring.

The springs are generally capable of supplying very small amounts of water & are, therefore, generally not regarded as sources of water supplies.

Types of Springs:

① Gravity Springs
② Surface Springs
③ Artesian Springs

④ Wells:

A water well is a ~~well~~ hole usually vertical, excavated in the earth for bringing ground water to the surface.

The wells may be classified into two types
(1) Open wells
(2) Tube wells.

(1) Open wells:
They are generally open masonry wells having comparatively bigger diameters and are suitable for low discharges of the order of 18 cubic metres per hour.
Types: (1) Shallow wells &
(2) Deep wells.

(2) Tube wells:
To obtain large discharge mechanically, tube well, which is a long pipe or a tube, is bored or drilled deep into the ground, intercepting one or more water bearing strata.
Types: (1) Cavity type tube wells &
(2) Screen type tube wells.

Quality and Quantity of ground water & its Usefullness for public water supplies:

Quality:
- The ground water supplies are generally purer and safer, because the water before getting stored in the underground reservoir undergoes natural filtration during the percolation through the soil pores.
- They are free from suspended impurities & organic matter
- Water is less likely to be contaminated by bacteria.

- They are likely to be contain greater amounts of dissolved salts, minerals, gases, etc. These may impart different tastes, odours, & some other properties such as hardness.
- Although the quality of ground water is quite safe, yet it is advisable to protect these sources from possible dangers of pollution.
- Ground waters are generally found colder in hot seasons & hotter in cold seasons, are thus, very useful for domestic uses.

Quantity:
- The Quantity of ground water available is generally less than that of surface sources.
- The amount of ground water available at a particular place depends upon the underground storage & the geological formations of the area.

Drinking Water Quality Standards:
- The water must be colourless, odourless and tasteless.
- Free from turbidity, excessive or toxic chemical compounds.
- Harmful micro-organisms & radio-activity must be absent.

Characteristics of Water:

1. Physical Characteristics
2. Chemical Characteristics
3. Biological Characteristics

① Physical Characteristics:

ⓐ Turbidity:

If a large amount of suspended matter such as clay, si[lt] or some other finely divided organic materials are present in water, it will appear to be muddy or cloudy or turbid in appearance.

The turbidity is measured by a turbidity rod or turbidimeter.

Turbidimeter Types: 1) Jackson's Turbidimeter
2) Bayli's Turbidimeter
3) Nephelometers

ⓑ Colour:

- Dissolved organic matter from decaying vegetables or some inorganic materials, such as coloured soils, etc, may impart colour to the water.
- The excessive growth of algae and aquatic micro-organisms may also sometimes impart colour to the water.
- Intensities of colour are determined using tintometer.

ⓒ Taste & Odour:

- Dissolved organic materials or inorganic salts, or the presence of dissolved gases such as H_2S, CH_4, CO_2, O_2 etc., combined with organic matter, mineral substances like NaCl, iron compounds, carbonates or sulphates may impart taste & odour to the water.

ⓓ Temperature:

Temperature for potable water - 10°c are highly desirable
- above 25°C are objectionable.

ⓔ Specific Conductivity of water:

The total amount of dissolved salts present in water can be easily estimated by specific conductivity of water.

2) Chemical Characteristics:

ⓐ Total Solids & Suspended solids:

- The total amount of solids present in water can be determined by evaporating a sample of water & weighing the dry residue left.

- The suspended solids can be found by filtering the water sample & weighing the residue left on filter paper.

- The difference between the total solids & the suspended solids is known as the amount of dissolved salts.

- Total permissable amount of solids is generally upto to 500ppm, although higher amounts upto 1000ppm are permitted

ⓑ pH value of water:

It indicates the logarithm of reciprocal of hydrogen ion concentration present in water.

$$pH = -\log_{10}[H^+]$$

- pH of water ranges from 0 to 14.
- If the pH of water is more than 7, it will be alkaline if it less than 7, it will be acidic.
- pH is measured with the help of Potentiometer and pH paper
- The permissable pH values for puplic supplies may range between 6.6 to 8.5.

(c) Hardness of water:

· It is that characteristics which prevents the formation of sufficient leather or foam, when such hard waters are mixed with soap.

- They are undesirable because they may lead to greater soap consumptions, scaling of boilers, causing corrosion & incrustation of pipes, making food tasteless, etc.

(d) Chloride Content:

- Chlorides are generally present in water in the form of sodium chloride & may be due to leaching of marine sedimentary deposits, pollution from sea water, industrial & domestic waste.
- Their concentration above 250 mg/l produce a salty taste in drinking water & are thus objectionable.

(e) Nitrogen:

It is the indication of presence of organic matter, &

may occur in one or more of the following forms

a) Free ammonia

b) Albuminoid (or) Organic nitrogen

c) Nitrites &

d) Nitrates.

f) Metal & Other Chemical Substances:

Tests are carried out in order to determine the amounts of various metals & other substances, such as iron, manganese, copper, lead, barium, cadmium, arsenic, selenium, flourine, etc., present in water.

g) Dissolved Gases

The various gases which may get dissolved in water due to its contact with the atmosphere or the ground surface may be, nitrogen, methane, hydrogen sulphide, carbon dioxide, and oxygen.

Biochemical Oxygen Demand (BOD)

The extent of organic matter present in water sample can also be easily estimated by supplying oxygen to this sample & finding the oxygen consumed by the organic matter present in water. This oxygen demand is known as Biochemical Oxygen Demand (BOD).

3) Bacterial & Microscopial Characteristics:

Most bacteria are harmless, and under certain conditions beneficial to human beings, animals & crops. This bacteria is known as non-pathogenic bacteria. or non pathogens.

- Certain other bacteria are the deadly foes of man & animals & may enter their tissues, causing severe water borne diseases such as cholera, typhoid, infectious hepatitis, etc. This bacteria is known as pathogenic bacteria or pathogens.

UNIT - II

CONVEYANCE FROM THE SOURCE

Introduction :

Whenever the water is withdrawn from a surface source such as a lake or a reservoir, then an intake structure must be constructed at the entrance of the conduit.

The basic function of the intake structure is to help in safely withdrawing water from the source over a predetermined range of pool levels & then to discharge this water into the with drawal conduit, through which it flows upto the water treatment plant.

Factors governing the Location of an Intake :

The site for locating the intake should be selected carefully keeping the following points in mind

1) The site should be near the treatment plant, so that the cost of conveying water to the city is less.

2) The intake must be located in the purer zone of the source.

3) The intake must never be located at the downstream or in the vicinity of the point of disposal of wastewater.

4) The intake should never be located near the navigation channels, as otherwise, there are chances of intake water getting polluted due to discharge of refuse and waste from

ships and boats.

5) The site should be such as to permit greater withdrawal of water, if required at a future date.

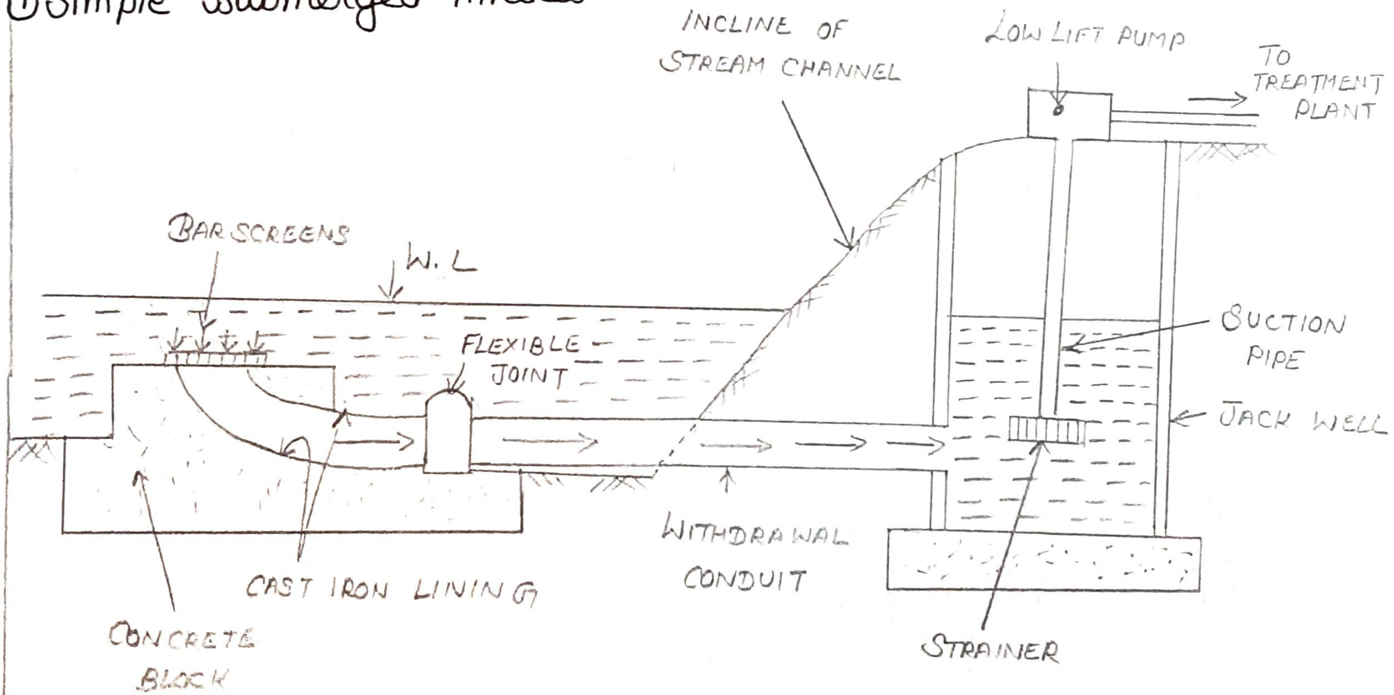
6) The intake must be located at a place from where it can draw water even during the driest period of the water.

7) The intake site should remain easily accessible during floods & should not get flooded.

8) The intakes should not be located on curves.

Types of Intakes:

① Simple submerged intakes



- It consists of a simple concrete block or a rock filled timber crib supporting the starting end of the withdrawal pipe.

- The withdrawal pipe is generally taken up to the sump well at shore, from where, the water is lifted by pumps.

- The intake opening is generally covered by screen so as to prevent the entry of debris, ice, etc into the withdrawal conduit.
- In case of lakes, where silt tends to settle down, the intake opening is generally kept at about 2 to 2.5m above the bottom of the lake & thus to avoid the entry of large amount of silt & sediment.
- These submerged intakes are cheap and generally do not obstruct navigation.
- They are therefore widely used for small water supply project drawing water from streams or lakes having relatively little change in water surface elevation throughout the year.
- The main disadvantage is that they are not easily accessible for cleaning, repairing, etc.

(2) Intake towers:

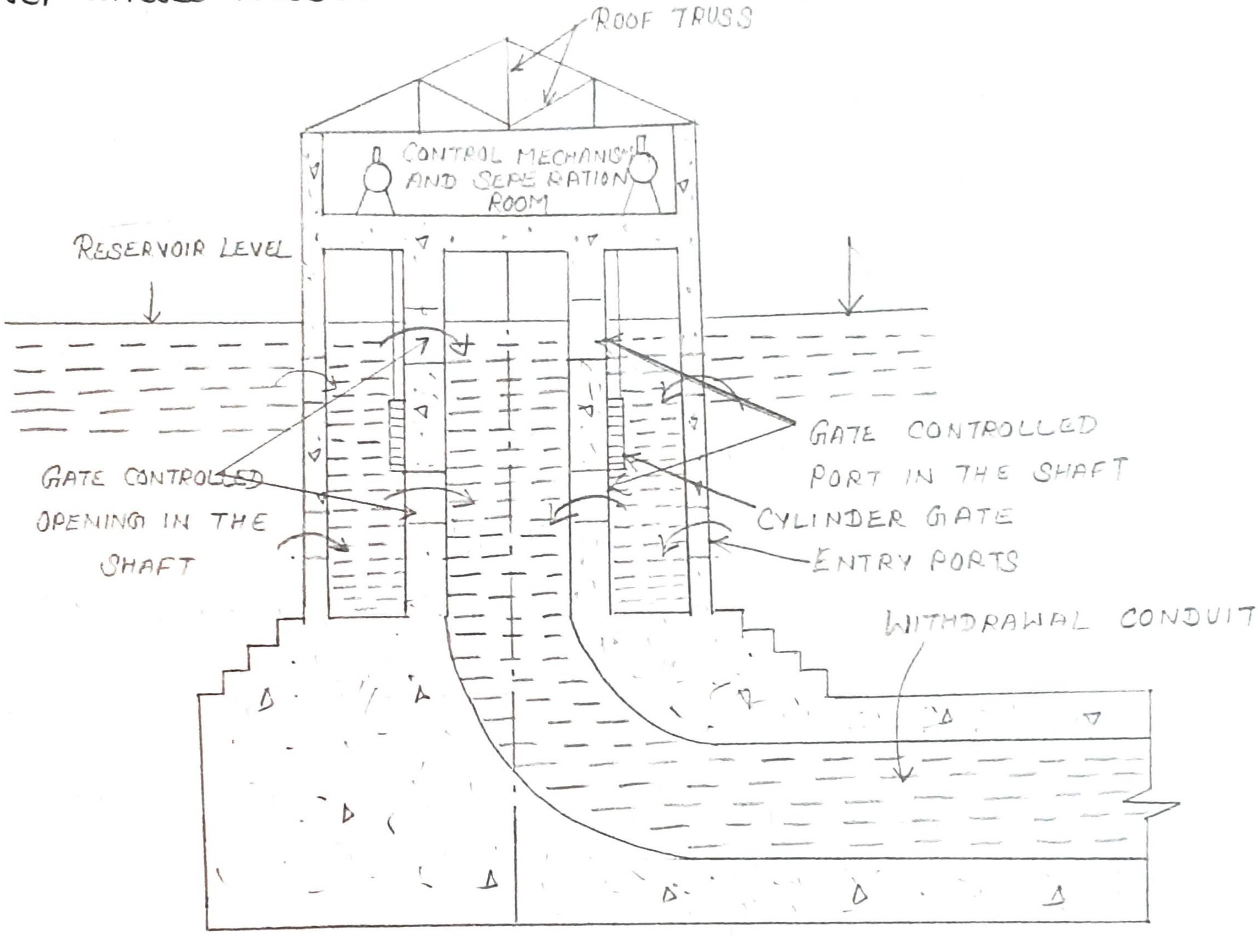
- They are generally used on large projects & on rivers or reservoirs where there are large fluctuations of water level.
- Gate controlled openings at various levels, called ports, are generally provided in these concrete towers, which may help in regulating the flow through the towers & permit some selection of the quality of water to be withdrawn.
- There are two major types of intake towers

④

into

i) Wet intake towers
ii) Dry intake towers

i) Wet intake towers



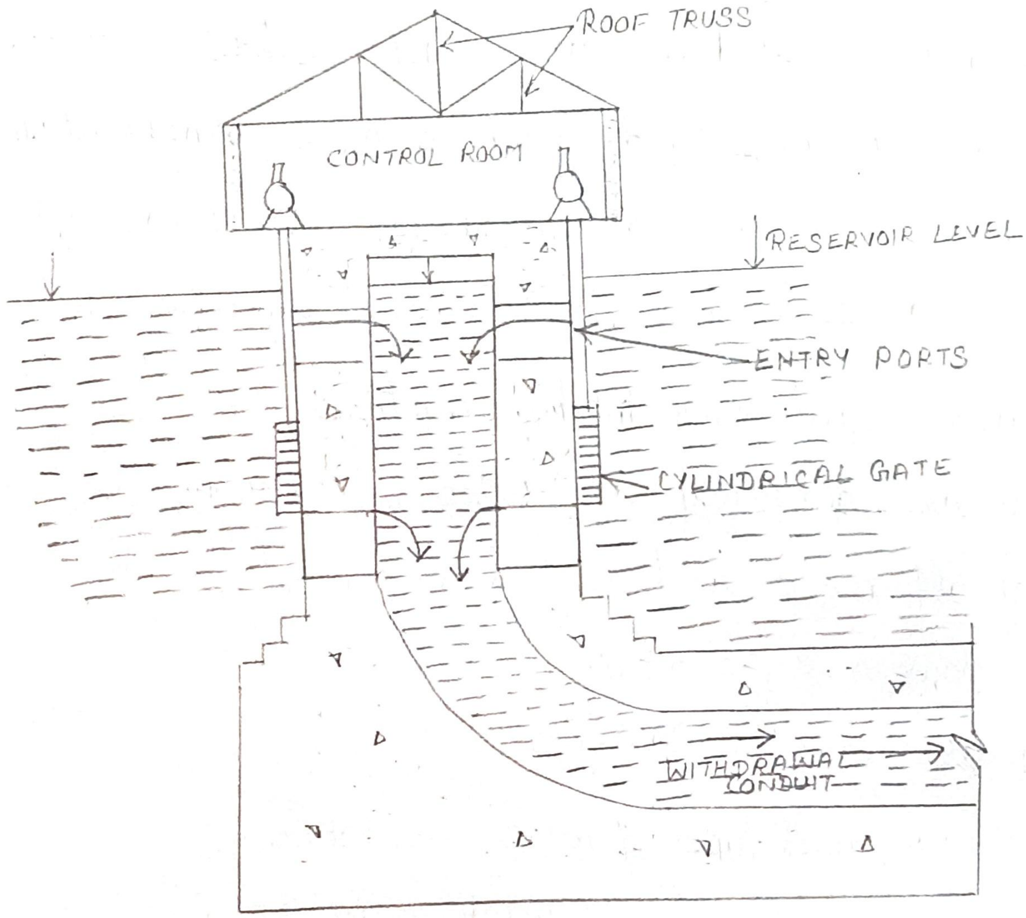
- It consists of a concrete circular shell filled with water upto the reservoir level and has a vertical inside shaft which is connected to the withdrawal pipe.
- The withdrawal may be taken directly to the treatment plant in case no lift is required or to the sump well in case a low lift is required.
- The withdrawal conduits may lie over the bed of the river or may be in the form of tunnels below the river bed.
- Openings are made into the outer concrete shell, as well as

into the inside shaft.

- Gates are placed on the shaft to control the flow of water.

- The water coming out of the withdrawal conduit may be taken to the pump house for lift, if the city water treatment plant is located at high elevation, or may be taken directly to the treatment plant, if it is situated at lower elevation.

ii) Dry intake towers:



- In a dry intake tower, the water is directly drawn into the withdrawal conduit through the gated entry ports.

- The dry intake tower have no water inside the tower if its gates are closed, whereas the wet intake tower will be full of water even if its gates are closed.

- When the entry ports are closed, a dry intake tower will be subjected to additional buoyant forces & hence, must be of heavier construction.

- In dry intake towers the water can be withdrawn from any selected level of the reservoir by opening the port at that level.

- The intake structures are huge structures therefore they should be located so as to not interfere with navigation.

- They must be properly designed so as to withstand the worst possible combinations of various forces, such as hydrostatic pressures, wind & earthquake forces, forces caused by waves, ice, debris, etc.,

③ Medium Sized River Intake Structures

- They are generally constructed for withdrawing water from almost all rivers and are a media between the submerged intake towers & the intake towers.

- They are broadly classified into

    i) Twin well type of intake structures
    ii) Single well type of intake structures

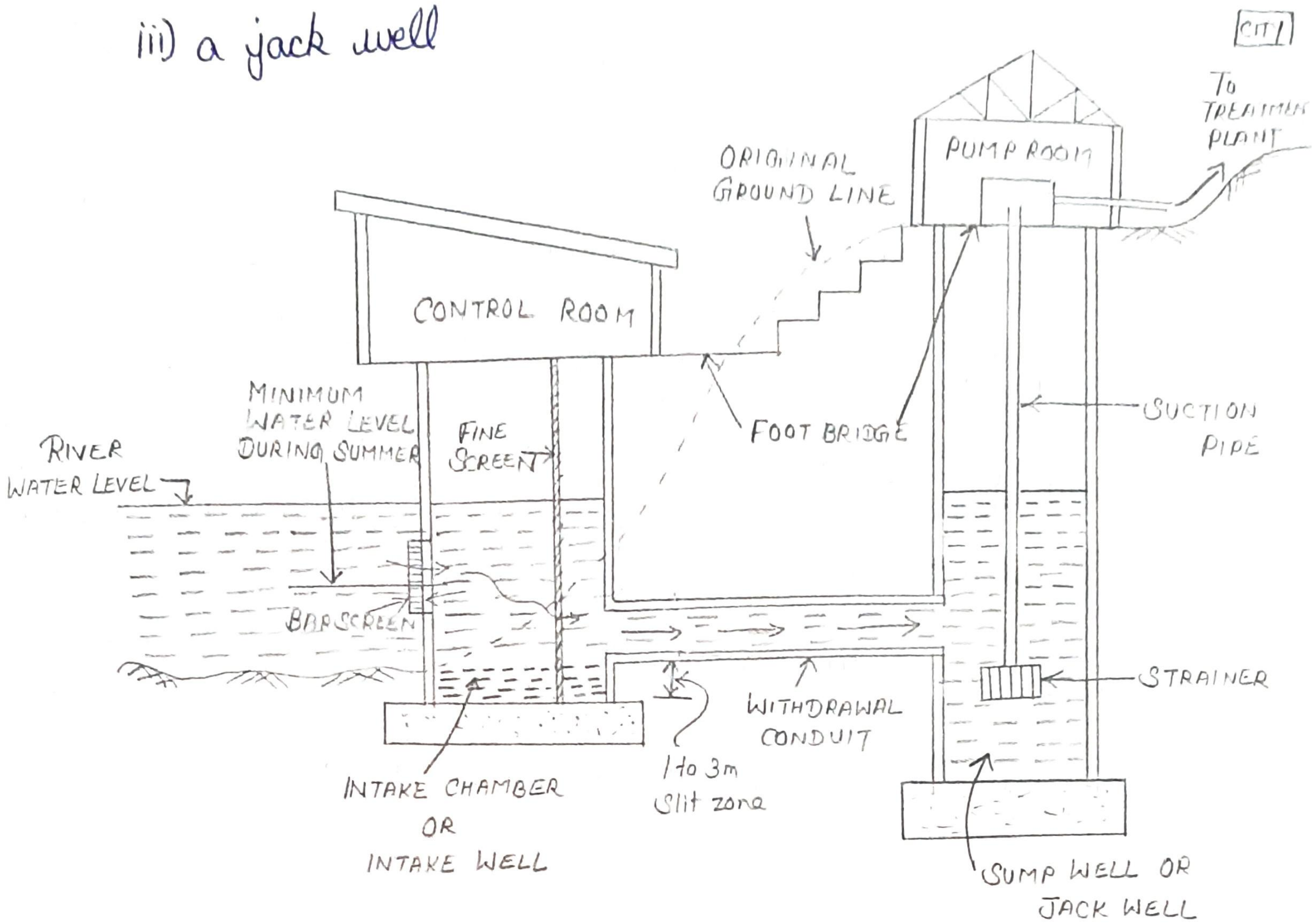
i) Twin well type of intake structures:

- They are constructed on all types of rivers, where the river water hugs the river bank.

- The typical river intake structure consists of

    i) an inlet well

ii) an inlet pipe &
iii) a jack well



- The inlet well is located in the river bed, somewhat away from the river bank, so that it always remains surrounded with water, even during low flow stage.
- The well is built in masonry or concrete, and is raised above the river HFL and covered at the top by wooden sleepers etc., as to make it approachable from the river bank through a foot bridge arrangement.
- The intake pipe connecting the intake well with the jack well is usually of a non-pressure type, & is laid with a gentle slope of 1 in 200 or so, towards

(8)

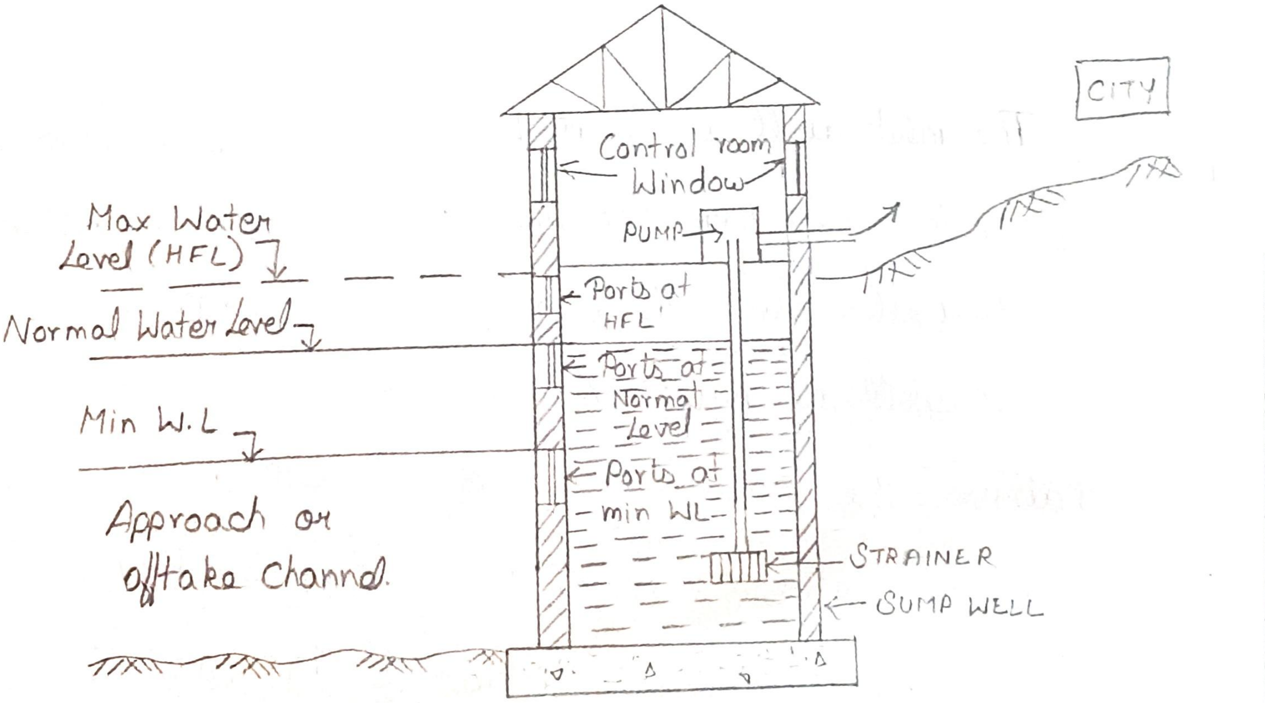
the jack well.

- The pipe size should be such that the flow vel. doesnot exceed about 1.2m/s.

- Water entering the jack well from the intake pipe is lifted by pumps and is fed into the rising main through the delivery pipe of the pump.

- The jack well should be founded on hard strata with a bearing capacity of not less than 450kN/m².

ii) Single well type of a river intake:



- In alluvial rivers, water is usually ponded up by constructing a weir across the river.

- From the upstream side of such a weir, a channel may sometimes be taken off, as in a usual diversion head works scheme.

- The water entering this offtake canal may then be collected and lifted for supply to the City Treatment Plant located at higher elevation.

- The intake structure for collecting water in such a case shall than be located in this off take channel.

- Similarly, sometimes, an approach channel may be excavated from the deep river towards the river bank up to the site of intake.

- In this situations, the intake structure may be constructed across the off-take or approach channel in the form of a single jack well, provided with direct entry ports.

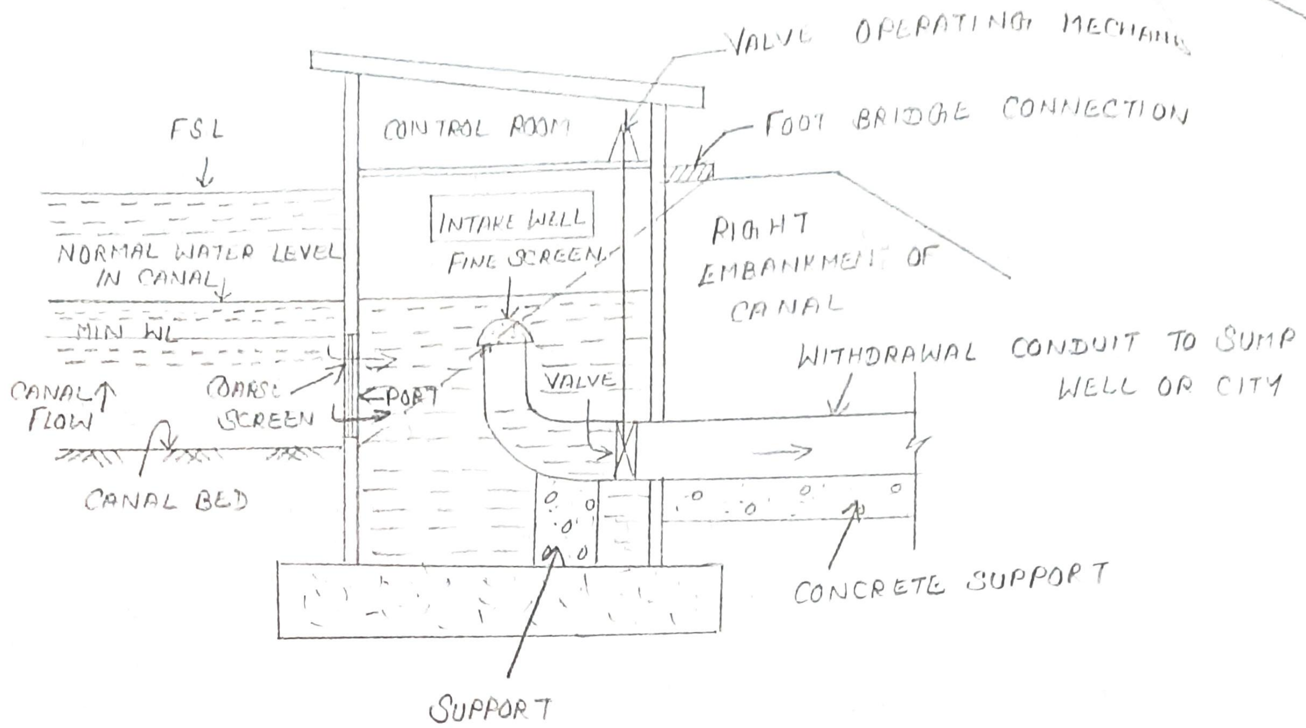
- This arrangement will eliminate the construction of a seperate inlet well & the inlet pipe, as are required in the twin well type of river intake.

④ Canal Intakes:

- In case of canals, the intake well is generally located in the bank of canal, and water enters the chambers through an inlet pipe, covered with a fine screen.

- The water coming out of the chamber through the outlet conduit may be taken to the sump well or city as desired.

(10)



- The entry of water in the intake well takes through a coarse screen, the top of which is generally provided at minimum water level in the canal, and bottom is about 0.15m above the canal bed to avoid entry of bed load.
- An additional fine screen is provided at the inlet end of the withdrawal conduit.
- An outlet valve, operating from the top, is provided to control the entry of water into the outlet pipe.
- The flow velocity through the outlet conduit is generally kept at about 1.5m/sec, and this helps in determining the area and dia at the withdrawal conduit.

Conduits for Transporting water:

- Conduits are pipes used for transporting water from the intake structures to the treatment plant & from the treatment plant to the puplic.

Types of Conduits:

1) Gravity Conduits

2) Pressure Conduits

1) Gravity Conduits

- They are those in which the water flows under the mere action of gravity.
- These conduits cannot go up and down hills & valleys as desired by the excisting topography of the area.
- Gravity conduits can be in the form of canals, flumes or aqueducts.

(a) Canals:

- They are open channels which are constructed by cutting high grounds and constructing banks on low grounds.
- They are generally constructed in balanced cut & fill & are cheap to build in suitable soil.
- They are generally not used for water not used for water supplies but are often used for irrigation.

(b) Flumes:

- Open channels supported above the ground over trestles, etc., are called flumes.
- They are used to convey water across valleys and minor depressions or over drains and other obstructions in their path.

ⓒ Aqueducts:

- They are closed, rectangular or circular or horse shoe section, built of masonry or RCC.
- They wind their way through landscape, with gradual slopes, like roads, railways & highways.
- Although they are covered or closed, yet water doesn't flow under pressure as they are not allowed to run full.

2) Pressure Conduits:

- They are closed conduits and as such no air can enter into them, the water flows under pressure above the atmospheric pressure.
- The pressure pipes can follow the natural available ground surface and can freely go up and down hills or can dip beneath valleys or mountains, sometimes even rising above the hydraulic gradient lines and thus requiring lesser length of conduit.
- The pressure aqueducts may be in the form of closed pipes or closed aqueducts and tunnels called pressure aqueducts or pressure tunnels designed for the pressure likely to come on them and for various other forces.
- The aqueduct as well as tunnel sections are generally kept circular for hydraulic as well as structural reasons.
- Due to their circular shape, every pressure conduit is generally termed as a pressure pipe.

- When a pressure pipe drops beneath a valley, stream or some other depression, it is called a sag, or a depressed pipe or an inverted siphon.
- They are economical than canals or flumes because they can generally follow shorter routes.
- The water moving through such a conduit is not exposed anywhere, and hence, there are no chances or very less chances of it getting polluted.

Hydraulics of Flow and Design of Pressure pipes as Gravity mains:

- It is a normal practice to design pipes in such a way that the available pressure head between the source & the city is just lost in overcoming the frictional resistance offered to the flow by the pipe interior.
- In addition to the head lost due to pipe friction there are minor losses caused by the abrupt changes in the flow geometry as a result of changes in pipe size, bends, valves & fittings of all types
- The head loss caused by pipe friction can be found by using either of the following formula.

1) Darcy - Weisbach formula
2) Manning's formula
3) Hazen - Williams formula
4) Modified Hazen Williams formula.

① Darcy - Weisbach Formula:

It is more than 100 years old formula & states that

$$H_L = \frac{f' . L}{d} . \frac{V^2}{2g}$$

Where, H_L = Head Loss in metres

L = Length of pipe in metres

d = Diameter of pipe in metres

V = Mean velocity of the flow through the pipe in m/sec.

g = Acceleration due to gravity

f' = Dimensionless friction factor generally varying between 0.02 to 0.075 & depends upon Reynold number (i.e. $Re = Vd/\nu$) and relative roughness of pipe.

② Manning's Formula:

$$H_L = \frac{n^2 . V^2 . L}{R^{4/3}}$$

Where, n = Manning's rugosity coefficient

L = Length of pipe in metres

V = Flow velocity through pipe in m/sec.

R = Hydraulic mean depth of pipe

$$= \left[\frac{A}{P} = \frac{\frac{\pi d^2}{4}}{\pi d} = d/4\right] \text{ in metres}$$

③ Hazen - William's Formula

This formula is widely used for pipe flows and states that

$$V = 0.85\, C_H . R^{0.63} . S^{0.54}$$

Where, C_H = Coefficient of hydraulic capacity

R = Hydraulic mean depth of pipe in metres = $(d/4)$ for circular pipes running full.

S = Slope of the energy line

V = Flow velocity through the pipe in m/sec.

Pipe Material	Value of C_H
Concrete	130
Cast Iron New 5 years old 20 years Old	 130 120 100
Welded Steel (New)	120
Riveted Steel (New)	110
Vitrified Clay	110
Bricks Sewers	100
Asbestos - Cement	140

④ Modified Hazen - William's Formula

$$V = \frac{3.83\, C_R \left[d^{0.6575} (g \cdot s)^{0.5525} \right]}{\nu^{0.105}}$$

Where, C_R = dimensionless coefficient of roughness

d = pipe diameter

g = acceleration due to gravity = $9.81\, m/s^2$

s = Friction slope = H_L / L.

ν = Viscosity of liquid

Problem

① Estimate roughly the sizes of supply conduits leading to adequate service reservoir, serving

a) a relatively small town of 25,000 population

b) a relatively large city with industrial establishments having a population of 5 lakh people.

Also find the hydraulic gradients at which the pipe lines are proposed to be laid. Assume any suitable data according to the Indian conditions, where required.

Solution:

Assumptions and Given Data:

Water Consumption

a) For town of 25,000 population = 120 litres / capita / day

b) For city with industrial establishment having a population of 5 lakhs = 270 litres / capita / day

Solution:

Average quantity of water required

a) For town = 120 × 25,000 = 3 million litres / day = 3 M.l.d

b) For city = 270 × 5,00,000 = 135 million litres / day = 135 M.l.d

Assuming maximum daily demand as 1.8 times the average, the maximum quantity of water required

a) For town = 1.8 × 3 = 5.4 M.l.d

$$= \frac{5.4 \times 10^6}{10^3 \times 24 \times 60 \times 60} = 0.063 \text{ cumecs.}$$

b) For city $= 135 \times 1.8 = 243$ M.l.d

$$= \frac{243 \times 10^6}{10^3 \times 24 \times 60 \times 60} \text{ cumecs}$$

$= 2.81$ cumecs

Assuming a flow velocity of 1.2 m/sec through the circular conduit, we get

a) For town, $Q = A.V$

$Q = 0.063$

$0.063 = A \times 1.2$

$A = 0.063/1.2 = 0.0525\ m^2$

(or) Area of the pipe required $= 525\ cm^2$

∴ Diameter of the pipe required

$$A = \frac{\pi d^2}{4}$$

$$525 = \frac{\pi \times d^2}{4}$$

$$\frac{525 \times 4}{\pi} = d^2$$

$d^2 = 668.45$

$d = 25.85$ cm

∴ Use 25cm dia pipe.

b) For City

$2.81 = A \times 1.2$

$A = 2.34\ m^2$

$\pi/4 \times d^2 = 2.34$

$d^2 = 1.73 m$

$\therefore$ Use 1.8 m dia pipe.

Hydraulic gradient by the Hazen-William's formula, $C_H = 110$

$$V = 0.85 C_H . R^{0.63} . S^{0.54}$$

$$= 0.85 \times 110 \times \left(\frac{d}{4}\right)^{0.63} \times S^{0.54}$$

$$= 93.5 \left(\frac{d}{4}\right)^{0.63} \times S^{0.54}$$

a) For town

$$V = 1.2 = 93.5 \left(\frac{0.25}{4}\right)^{0.63} \times S^{0.54}$$

$$1.2 = 93.5 \times 0.1787 \times S^{0.54}$$

$$S^{0.54} = 1.2 / 93.5 \times 0.1787$$

$$S^{0.54} = 1.2 / 16.78$$

$$= \frac{1}{\frac{16.78}{1.2}}$$

$$S^{0.54} = \frac{1}{13.98}$$

$$S = \left(\frac{1}{13.98}\right)^{1/0.54}$$

$$S = \left(\frac{1}{13.98}\right)^{1.85}$$

$$= \frac{1}{(13.98)^{1.85}} = \frac{1}{132}$$

Thus, the hydraulic gradient is $1/132$ i.e., 1m fall in 132m length

b) For city:

$$V = 1.2 = 93.5\left(\frac{1.8}{4}\right)^{0.63} S^{0.54}$$

$$1.2 = 93.5 \times 0.605 \times S^{0.54}$$

$$\frac{1.2}{93.5 \times 0.605} = S^{0.54}$$

$$S^{0.54} = \frac{1.2}{56.57}$$

$$S^{0.54} = \frac{1}{47.14}$$

$$S = \left(\frac{1}{(47.14)}\right)^{1/0.54}$$

$$S = \frac{1}{47.14^{1.85}}$$

$$S = \frac{1}{1247}$$

Hence, the hydraulic gradient is $\frac{1}{1247}$ i.e., 1 m fall in 1247 m length.

② Estimate the hydraulic gradient in a 2m diameter smooth ~~concrete~~ concrete pipe carrying a discharge of 3 cumecs at 10°c temperature by using a) Darcy-Weisbach formula; b) by Manning's formula, c) by Hazen-William's formula; d) by Modified Hazen William's formula. Assume suitable data not given.

Solution:

Q = 3 cumecs

Dia of pipe = 2m

(20)

b) (i)

Area of pipe $= A = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 2^2 = 3.14 m^2$

$\therefore$ Velocity of flow $= V = Q/A = \frac{3}{3.14} = 0.955 m/sec$

a) Darcy - Weisbach Formula

$$H_L = \frac{f'L}{d} \cdot \frac{V^2}{2g}$$

Let us evaluate f',

Now, R_e = Reynold number $= Vd/\nu$

Where, ν = kinematic viscosity of water at $10°C$

$= 1.31 \times 10^{-6} m^2/sec$ (Value taken from Table 9.1 pg. no. 448)

$$R_e = \frac{0.955 \times 2}{1.31 \times 10^{-6}} = 1.46 \times 10^6 = 14,60,000$$

We have

$$f' = 0.005 + \frac{0.396}{R_e^{0.3}}$$

$$= 0.005 + \frac{0.396}{(14,60,000)^{0.3}} = 0.005 + \frac{0.396}{70.68}$$

$= 0.005 + 0.0056$

$= 0.0106 \simeq 0.011$

$$H_L = \frac{0.011 \times L}{2} \cdot \frac{(0.955)^2}{2 \times 9.81}$$

$$\frac{H_L}{L} = \frac{0.0103}{39.24} = \frac{1}{3810}$$

Thus, the hydraulic gradient is $\frac{1}{3810}$, i.e., 1m fall in 3810 m length.

b) Using Manning's formula

$$H_L = \frac{n^2 V^2}{R^{4/3}} \cdot L$$

Using $n = 0.013$, $R = d/4 = 2/4 = 0.5\ m$

$$\frac{H_L}{L} = \frac{(0.013)^2 \times (0.955)^2}{(0.5)^{4/3}}$$

$$= \frac{1.541 \times 10^{-4}}{0.396}$$

$$= \frac{1}{2575}$$

Thus, the hydraulic gradient is $\frac{1}{2575}$, i.e. 1m fall in 2575m length.

c) Using Hazen - William's formula

$$V = 0.85\ C_H \cdot R^{0.63} \cdot S^{0.54}$$

Using $C_H = 130$ (from table 6.2 in pg.no 264)

We have $0.955 = 0.85 \times 130 \times \left(2/4\right)^{0.63} \cdot S^{0.54}$

$$0.955 = 71.40 \times S^{0.54}$$

$$S^{0.54} = \frac{0.955}{71.40}$$

$$S^{0.54} = \frac{1}{74.8}$$

$$S = \left(1/74.8\right)^{1/0.54}$$

$$S = \frac{1}{(74.8)^{1.85}}$$

$$S = 1/2929$$

Thus the hydraulic gradient is $\frac{1}{2929}$ i.e 1m fall in 2929 length.

d) Modified Hazen - William's formula

$$V = 143.534\, C_R \cdot R^{0.6575} \cdot S^{0.5525}$$

$V = 0.955\ m/s$, $C_R = 1.0$ (Table 6.3 pg No 266)

$R = d/4 = 2/4 = 0.5\ m$

$$0.955 = 143.534 \times 1 \times (0.5)^{0.6575} \times S^{0.5525}$$

$$S^{0.5525} = \frac{0.955}{90.997}$$

$$S^{0.5525} = \frac{1}{95.28}$$

$$S = \left(\frac{1}{95.28}\right)^{1/0.5525}$$

$$S = \frac{1}{95.28^{1.81}}$$

$$S = \frac{1}{3819}$$

Thus the hydraulic gradient is $\frac{1}{3819}$ i.e, 1m fall in 3819m length.

Forces acting on Pressure Conduits

The following forces generally comes in the pressure pipes

1) Internal pressure of water including water hammer pressure.

2) Pressure due to external loads in the form of backfill, traffic loads.

3) Longitudinal temperature stresses created when pipes are laid above the ground.

4) Longitudinal stresses created due to unbalanced pressures at bends, or at points of changes of cross section.

5) Flexural stresses produced when pipes are supported over trestles, etc.

Working Pressure:

It may be defined as the actual maximum pressure to which the pipe will be subjected during its operation.

Design Pressure:

It may be defined as the maximum pressure for which the pipe has been designed.

Test Pressure:

It may be defined as the maximum pressure which the pipe can withstand without any leakage when tested for hydrostatic pressure in accordance with the standard method of testing.

Various Types of Pressure Pipes:

Depending upon the construction material, the pressure pipes are of the following types

1) Cast iron pipes

2) Steel pipes

3) Reinforced cement concrete pipes
4) Hume Steel Pipes
5) Vitrified Clay pipes
6) Asbestos cement pipes
7) Miscellaneous types of pipes.

The selection of a particular type of material for a pipe depends mainly upon the relative economy, the pressure likely to come and the working pressures, maximum permissible sizes and capacities, availability of material and labour for their construction, etc.,

Laying of Water Supply Pipes:

- Pipes are used for conveying water from the source to the city, and also for distributing the same within the city among the consumers.
- When pipes are used for bringing water from the source to the city, only one or two lines of the same size are generally laid, whereas when they are used for distributing water, they are of varying sizes, having many connections & branches.
- Pipes are laid either above the ground or below the ground.
- The pipes bringing water from the source to the city, are laid on the ground, whereas the distributing mains taking the water within the localities, are laid below the roads & streets.

- The pipe lines, in general, should follow the profile of the ground.
- When pipes are laid on the ground, they must be laid on a well compacted formation of suitable width so as to avoid future settlement.
- They may be laid directly over the compacted soil formation or may be laid over small masonry or cement concrete supports at 6 to 12m apart.
- This arrangement, though costly, facilitates inspection, maintenance, repairs, etc and is generally adopted these days.
- When pipes are buried under the ground, they are laid in trenches excavated upto the required depths.
- The top of the pipe is generally kept about 1m below the road surface, so as to minimize the impact and traffic loads, transmitted to the pipes.
- The width of the trench is generally kept 30 to 50cm more than the outside diameter of the pipe.

Pipe Appurtenances:

In order to isolate and drain the pipe line sections for tests, inspections, cleaning and repairs, a number of appurtenances such as

1) Gates & Valves in Pipe Lines

(26)

a) Gate valves or Sluice valves

b) Air valves

c) Blow off valves

d) Pressure - relief valves

e) Check valves or reflux valves

2) Manholes

3) Insulation Joints

4) Anchorages

① Gate valves (or) Sluice valves:

- Gate or Sluice valves are used to regulate the flow of water through the pipes.

- They are located along the pipe line at intervals of about 3 to 5 km, so as to divide the pipe line into different sections.

② Air valves:

- They are the kind of valves which are generally placed along the pipe line at "summits" on both sides of the sluice valves & also on the downstream side of all other sluice valves

③ Blow valves:

- In order to remove the entire water from within a pipe (after closing the supply), small off-takes are provided at low points. These valves are known as blow off valves or drain valves.

④ Pressure-relief valves:

Water hammer pressure in pressure pipes can be reduced by using pressure relief valves.

Such a valve is adjusted to open out immediately and automatically as soon as the pressure in the pipe exceeds a certain fixed predetermined valves.

⑤ Check Valves:

They are called non-return valves because they prevent water to flow back in the opposite direction.

They are installed on the delivery side of the pumping set, They are installed on the delivery side of the pumping set, so as to prevent the back flow of stored or pumped water, when the pump is stopped.

⑥ Manholes:

They are provided at suitable intervals along the pipe line, so as to help its laying, and to serve for inspections and repairs.

⑦ Insulation joints:

They are provided at suitable intervals along the pipe line at suitable intervals, so as to insulate the pipe against the flow of stray electric currents, & thus to check electrolysis.

⑧ Anchorages:

The pipes try to pull apart and get out of the alignment at bends & other points of unbalanced pressure.

In order to prevent the pipes from pulling apart, pipes are anchored by firmly embedding these portions in massive blocks of concrete or masonry, which absorbs the side thrust.

Testing of the Pipe Lines:

① The pipe line is tested from section to section. Thus at a time only one particular section lying between two sluice valves is taken up for testing.

② The downstream side sluice valve is closed, & the water is admitted into the pipe through the upstream sluice valve.

③ The upstream valve, through which water was admitted is closed and completely isolated from the rest of the pipe.

④ Pressure gauges are then fitted along the length of pipe section at suitable intervals, through holes left for this purpose

⑤ The pipe section is then connected to the delivery side of the pump through a small by-pass valve, & the pump is started, so as to develop pressure in the pipe. The operation is continued till the pressure inside the pipe reaches the designed value, which can be read from the pressure gauges fixed on the pipe.

(6) The by-pass valve is then closed, and the pumping is discontinued.

(7) The pipe is thus kept under pressure for 24 hours, & inspected for possible defects, leakages at the joints, etc. This completes the pressure test.

Disinfection of Pipe Lines before Use:

- The pipes are disinfected by keeping them full with water & adding chlorine in amounts, as to maintain a residue of 50mg/l.
- This residue is maintained for 12 hours and the pipe is emptied and flushed with fresh treated water, thus making the pipe ready for carrying potable water to the consumer or to the storage tanks.

Pumps:

Pumps are required at one or more of the following stages

i) To lift the water at the source, when the water cannot flow by gravity into the mains.

ii) To lift the water at the treatment plant, if sufficient natural slope is not available.

iii) To lift the water after the treatment, so as to force the water into the distributing mains.

iv) When the pressure in the distributing mains has to be increased or boosted at some intermediate points within the distribution system, so as to enable the water to reach upto the required height.

Types of Pumps:

1. Roto dynamic Pumps
2. Displacement Pumps

① Rotodynamic Pumps:

The pump has a wheel or a rotating element which rotates the water in a casing, & thus imparting energy to the water.

They are of the following two types

a) Centrifugal Pump
b) Axial-flow Pump

② Displacement Pumps:

It works on the principle of mechanically inducing vacuum in a chamber, thereby drawing in a volume of water which is then mechanically displaced & forced out of the chamber.

They are of the following two types

a) Reciprocating Pumps &
b) The rotary type Pump.

Factors Affecting the selection of a particular type of pump.

1) Capacity of pumps
2) Importance of water supply schemes
3) Initial cost of pumping arrangement
4) Maintenance cost
5) Space requirements for locating the pump
6) Number of units required
7) Total lift of water required
8) Quantity of water to be pumped.

Pumping Stations:

The location of a pumping station is primarily governed by the location of a place from where it is to receive water, & also by the location of the place where it is to supply that water.

The points to be kept in mind while selecting a suitable site are as follows

i) The site should be away from all the sources of contamination or pollution.

ii) The site should be above the highest flood level of the river.

iii) It should be so selected that its future growth & expansion is easily possible.

iv) In case of rivers, the site for the pumping stations should be such that the pumping machinery is able to draw sufficient water so as to meet the peak demand during the busiest hour of the day.

v) Possibilities of the hazard due to fire should also be considered while selecting the site for pumping station.

vi) The proximity of the site to the railways, from where the coal can be quickly made available for producing power, may also have to be considered.

Piping & Valves at the Pumping Stations:

1. Sluice (or) gate valves
2. Check valves
3. Pressure relief & air valve on the delivery side.

UNIT-III

WATER TREATMENT

- The available raw waters must be treated & purified before they can be supplied to the general public for their domestic, industrial or any other uses.
- The extended treatment required to be given to a particular water depends upon the characteristics & quality of water & also upon the quality requirements for the intended use.
- The available water must be made safe, good in appearance, and attractive to human taste & tongue.
- The method or methods adopted for purification depends mostly upon the character of the raw water.

Methods of Purification of Water:

The various methods or the techniques which may be adopted for purifying the public water supplies are

1) Screening
2) Plain Sedimentation
3) Sedimentation aided with coagulation
4) Filtration
5) Disinfection
6) Aeration
7) Softening
8) Miscellaneous treatment

Unit Operation:

It is defined as the process which does not involve any chemical reaction.

It deals only with physical changes of the materials involved in the processess.

Unit Process:

It is defined as the process in which chemical changes takes place.

Treatment Process:

① Screening:

- The big and visible objects, such as trees, branches, sticks, vegetation, fish, animals, etc., present in raw waters of surface sources can be removed by screening.
- Screens are generally provided in front of the pumps or the intake works, so as to exclude the large sized particles.

Types of Screens:

① Coarse Screens

② Fine Screens

- Coarse screens are placed in the front of the fine screens.
- Coarse screens consist of parallel iron rods placed vertically or at a slight slope of about 2 to 10 cm centre to centre

- The fine screens are made up of fine wire or perforated metal with openings less than 1cm wide.
- The coarse screens first removes the bigger floating bodies & the organic solids.
- The fine screens then removes the fine suspended solids.
- The fine screens normally get clogged, & are to be cleaned frequently.
- The coarse screens are normally kept inclined at about 45°–60° to the horizontal, so as to increase the opening area to reduce the flow velocity, & thus making the screening more effective.
- While designing the screens, clear openings should have sufficient total area, so that the velocity through them is not more than 0.8 to 1m/sec.
- The materials which is collected on the upstream side of the screens is removed either manually or mechanically.

(ii) Sedimentation:

- The coarser suspended particles can be removed by letting the water settle in sedimentation basins. The process is called plain sedimentation.
- Most of the suspended impurities present in water do have a specific gravity greater than that of water.
- In still water, impurities will tend to settle down under

gravity, although in normal raw supplies, they remain in suspension, because of the turbulence in water.

- Hence, as soon as the turbulence is retarded by offering storage to the water, these impurities tend to settle down at the bottom of the tank, offering such storage. This is the principle behind sedimentation.
- The basin in which the flow of water is retarded is called the settling tank or sedimentation tank or sedimentation basin or clarifier.
- The theoretical average time for which the water is detained in the tank is called the detention period.

Theory of Sedimentation:

The settlement of a particle in water brought to rest is opposed by the following factors

i) The velocity of flow
ii) The viscosity of water
iii) The size, shape & specific gravity of the particle.

The settling velocity of a spherical particle is expressed by the Stoke's law, which takes the above three factors into account. The Stoke's equation is expressed as

$$V_S = \frac{g}{18}(G-1)\frac{d^2}{\nu} \quad \text{for } d < 0.1\,mm$$

Where, V_s = velocity of settlement of particle

d = diameter of the particle in m.

G = Sp. gravity of the particle $= \frac{\rho_s}{\rho_w} = \frac{\text{density of particle}}{\text{density of water}}$

ν = kinematic viscosity of water in m^2/sec.

Problem

① Find the settling velocity of a discrete particle in water under conditions when Reynold's number is less than 0.5. The diameter and specific gravity of the particle is 5×10^{-3} cm & 2.65 respectively. Water temperature is 20°C (Kinematic viscosity ν of water at 20°C $= 1.01\times10^{-2}\ cm^2/sec$).

Solution:

$$V_s = \frac{g}{18}(G-1)\frac{d^2}{\nu} \quad \text{When } d < 0.1mm$$

Where, $G = 2.65$

$d = 5\times10^{-3}$ cm $= 0.05$ mm, which is < 0.1 mm

$\nu = 1.01\times10^{-2}\ cm^2/sec$

$g = 9.81\ m^2/sec = 981\ cm^2/sec$.

$$V_s = \frac{981}{18}\times(2.65-1)\times\frac{(5\times10^{-3})^2}{1.01\times10^{-2}}$$

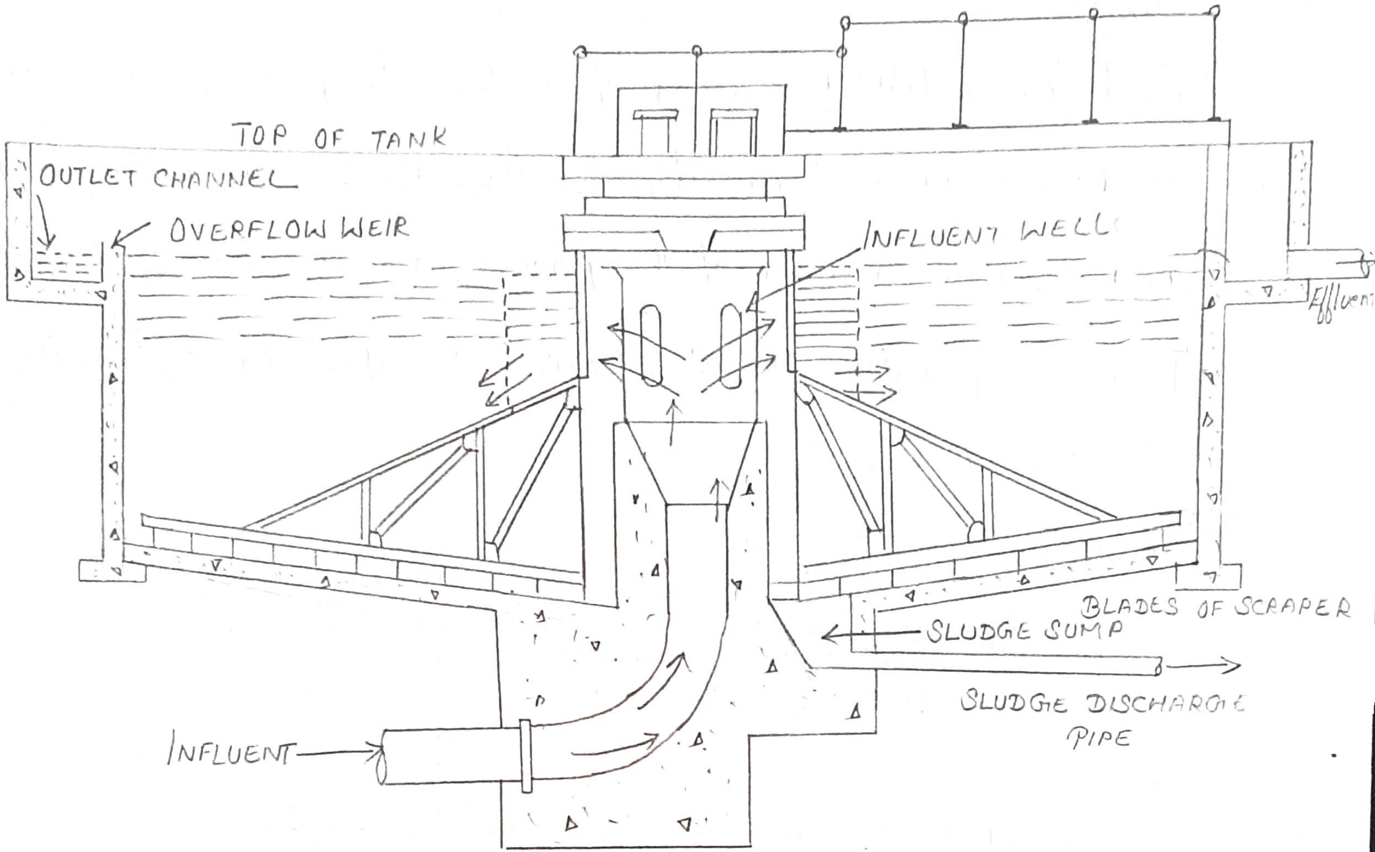
$$= \frac{981}{18}\times\frac{1.65\times25\times10^{-6}}{1.01\times10^{-2}}\ cm/sec$$

$$\boxed{V_s = 0.22\ cm/sec}$$

Types of Sedimentation Tanks:

1. Horizontal flow tanks
2. Vertical (or) up flow tanks

They may be rectangular or circular in plan.



Problem:

1) 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 for the raw supplies, assuming a detention period of 6 hours and the velocity of flow as 20 cm per minute.

Solution:

Quantity of water to be treated in 24 hours

$= 12 \times 10^6$ litres

Quantity of water to be treated during the detention period of 6 hours $= \frac{12 \times 10^6 \times 6}{24}$ litres

$= 3 \times 10^6$ litres

$= 3 \times 10^3$ cubic metres

$= 3000$ cu.m.

∴ The capacity of the tank required $= 3000$ cu.m

Velocity of flow to be maintained through the tank

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

The length of the tank required

= Velocity of flow × Detention period

$= 0.2 \times 6 \times 60 = 72$ m

Cross sectional area of the tank required

$= \frac{\text{Capacity of the tank}}{\text{Length of the tank}}$

$= \frac{3000}{72}$ m²

$= 41.67$ m² $\simeq 41.7$ m²

Assuming the depth of water in the tank as 4m, the width of the tank required $= \frac{41.7}{4} = 10.42$ m $\simeq 10.5$ m

Use a free board of 0.5m, the overall depth

$= 0.5$m $+ 4$m $= 4.5$ m

Hence, a rectangular sedimentation tank with an overall size of 72m × 10.5m × 4.5m can be used

2) A circular sedimentation tank fitted with standard mechanica 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 the raw water to be treated per day

$= 3.5 \times 10^6 \, l/day.$

∴ Quantity of the raw water to be treated during the detention period of 5 hours, i.e., the capacity of the tank

$$= \frac{3.5 \times 10^6 \times 5}{24} \text{ litres}$$

$= 728 \times 10^3$ litres

$= 728$ cu.m

The capacity of a circular tank of depth H and dia d is given by

$$\text{Volume} = d^2(0.011d + 0.785H)$$

$$728 = d^2(0.011d + 0.785 \times 3)$$

$$728 = d^2(0.011d + 2.255)$$

$$d = 17.3 \text{ m.}$$

(11) Sedimentation Aided with Coagulation:

- Very fine suspended mud particles and the colloidal matter present in water cannot settle down in plain sedimentation tank of ordinary detention period.

- They can be removed easily by increasing their size by changing them into flocculated particles.

- For this purpose, certain chemicals, called coagulants, are added to the water, which on thorough mixing, form a gelataneous precipitate, called "floc".

- The very fine colloidal particles present in water, get attracted and absorbed in these flocs, forming the bigger size flocculated particles.

- The colloidal particles do, infact, possess surface charges resulting from preferential adsorption or from ionisation of chemical groups on the surface.

- Most of the colloidal particles in water or wastewater are negatively charged.

- The surface charges on colloidal particles gives them long-term stability, and hence the particles which might otherwise settle are mutually repelled by their like charges.

- Coagulation is a chemical technique which is directed towards the destabilisation of the charged colloidal particles.

- Flocculation on the other hand, is the slow mixing technique which promotes the agglomeration of the stabilised particles.

- The entire process of addition of chemicals & mixing is is known as coagulation.

- The coagulated water is finally made to pass through the sedimentation tank, where the flocculated particles settle dow & are thus removed.

Chemicals used for coagulation:

- Various Chemicals such as alum, iron salts like ferrous sulphate, ferric chloride, ferric sulphate, etc., are generally used as coagulants.

- These chemicals are most effective when water is slightly alkaline.

- In the absence of alkalinity in raw water external alkalies like sodium carbonate, or lime, etc., are added to the water, so as to make it slightly alkaline, & thus to increase the effectiveness of the coagulants.

Constituents of a Coagulation Sedimentation Plant

The coagulation sedimentation plant or a clariflocculator contains the following four units

1) Feeding device
2) Mixing device (or) Mixing basin
3) Flocculation tank (or) Flocculator
4) Settling (or) Sedimentation tank.

(1) Feeding Devices:

- The chemical coagulant may be fed into the raw water either in a powdered form or in a solution form.

Dry Feeding - Powdered form

Wet Feeding - Solution form.

- Wet feeding equipments are generally costlier than the dry feeding equipments, but they have the advantage that they can be easily controlled & adjusted.

- The choice between these two types of equipments depends upon the following factors

a) The characteristics of the coagulant & the convenience with which it can be applied.

b) The amount of coagulant to be used.

c) The cost of the coagulant & the size of the plant.

(2) Mixing Devices:

- After the addition of the coagulant to the raw water, the mixture is thoroughly & vigorously mixed, so that the coagulant gets fully dispersed into the entire mass of water.

- It can be achieved by means of mixing devices, such as, centrifugal pumps, compressed air, mixing basins, etc.

- Out of these devices, mixing basins are most important & normally adopted.

- There are two types of mixing basins, viz.

a) Mixing basins with baffle walls

b) Mixing basins equipped with mechanical devices.

(IV) Filtration:

- Screening & sedimentation removes a large percentage of the suspended solids & organic matter present in raw supplies.
- The percentage of removal of the fine colloidal matter increases when coagulants are also used before sedimentation.
- But however, the resultant water will not be pure, & may contain some very fine suspended particles & bacteria present in it.
- To remove or to reduce the remaining impurities still further, and to produce potable and pelatable water, the water is filtered through the beds of fine granular materials, such as sands, etc.
- The process of passing the water through the beds of such granular materials is known as filtration.
- Filtration may help in removing colour, odour, turbidity and pathogenic bacteria from the water.
- Two types of filters are used for treating municipal water supplies. They are

i) The slow sand gravity filters and
ii) The rapid sand gravity filters

Theory of Filtration:

The filters purify the water under four different processes.

They are

i) Mechanical Straining
ii) Flocculation & Sedimentation

iii) Biological metabolism

iv) Electrolytic changes

Filter Materials:

① Sand

The filter sand should generally be obtained from rocks like quartzite, & should contain the following properties

i) It should be free from dirt & other impurities.

ii) It should be uniform in nature and size

iii) It should be hard & resistant

iv) It should be such as not to loose more than 5% of its weight after being placed in hydrochloric acid for 24 hours.

The selection of the correct effective size is very important, because too smaller size will lead to very frequent clogging of filters, and will give very low filtration rates.

Similarly, too large size will permit the suspended particles and bacteria to pass through it, without removing it.

② Gravel:

The gravel which may be used below the sand should be hard, durable, free from impurities, properly rounded, & should have a density of about 1600 kg/m3.

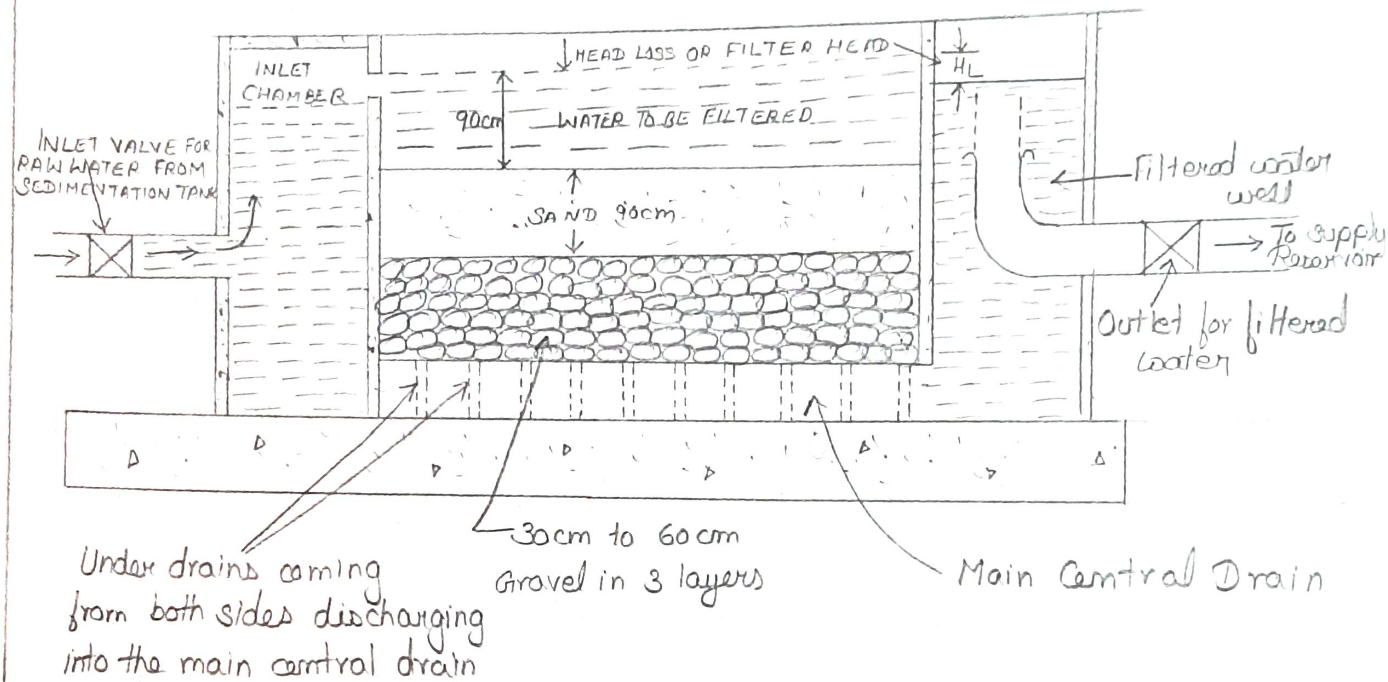
Types of Filters & Their Classification

Filters
- Slow Sand Filters
- Rapid Sand Filters
  - Rapid Gravity Filters
  - Pressure Filters

(14)

Slow Sand Filters

- Slow Sand filters are useful in the sense that they can remove much larger percentage of impurities and bacteria from the water.
- Slow sand filters yield a very slow rate of filtration and require large areas and are costly



Construction :

1) Enclosure tank:

- It consists of an open water-tight rectangular tank, made of masonry or concrete.
- Depth of tank - 2.5 to 3.5 m
- Area of tank - 2000 sq. m or more

2) Filter media:

- Consist of sand layers - 90 to 110 cm in depth
  - Effective size - 0.2 to 0.4 mm
  - Uniformity Coefficient - 1.8 to 2.5 or 3

③ Base material:

- The base material is gravel. It consists of 30 to 75 cm thick gravels of different sizes, placed in layers.

- Generally 3 to 4 layers each of 15-20 cm depth are used.

- Size of gravel - Bottom most layer - 40 to 65 mm
  Intermediate layer - 20 to 40 mm & 6 to 20 mm
  Top most layer - 3 to 6 mm

④ Under-drainage System

- It consists of a central drains & lateral drains.

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

⑤ Inlet and Outlet Arrangement

- Inlet chamber constructed for admitting the effluent from the plain sedimentation tank without disturbing the sand layers.

- In order to maintain a constant discharge through the filter, an adjustable telescopic tube is used.

Uses of Slow Sand Filters:

1) Suited for smaller plants & for purifying water with low colours, low turbidities & low bacterial contents.

2) Preferred for smaller plants for village supplies or for individual industrial supplies.

Problem:

1) Design six slow sand filter beds from the following data

(16)

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

Assume max. demand as 1.8 times the average daily demand.
Also assume that one unit, out of six, will be kept as stand by.

Solution:

Average daily demand = Population × Per capita demand
= 50,000 × 150 litres/day
= 7.5×10^6 l/day

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

Rate of filtration per day = (180 × 24) = 4320 l/sq.m/day.

Total surface area of filters required

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

$$= \frac{13.5 \times 10^6}{4320} = 3125 \text{ sq.m}$$

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

∴ The area of each filter unit

= 1/5 × Total area required = 1/5 × 3125

= 625 sq.m.

Now, if L is the length & B is the breadth of each unit then $L = 2.B$ (given)

$$2B \cdot B = 625$$

$$B^2 = 312.5 \text{ sq.m}$$

$$B = 17.67 \text{ m} \text{ ; say } 18 \text{ m}$$

$$L = 2(17.75) = 36 \text{ m.}$$

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

Rapid Sand Filters (or) Mechanical Sand Filters:

In order to reduce the requirements of space & increase the rate of filtration, a lot of research was conducted, which finally led to the development of rapid sand filters.

Types:

① Rapid pressure filters

One which utilises the development of pressure over the filtering water & thereby increasing the rate of filtration.

② Rapid Gravity filters:

One which utilise comparatively larger sized sand particles, which allow greater rate of filtration as compared to that of slow sand filters.

Construction

① Enclosure tank:

It consists of an open water tight rectangular tank, made of masonry (or) concrete

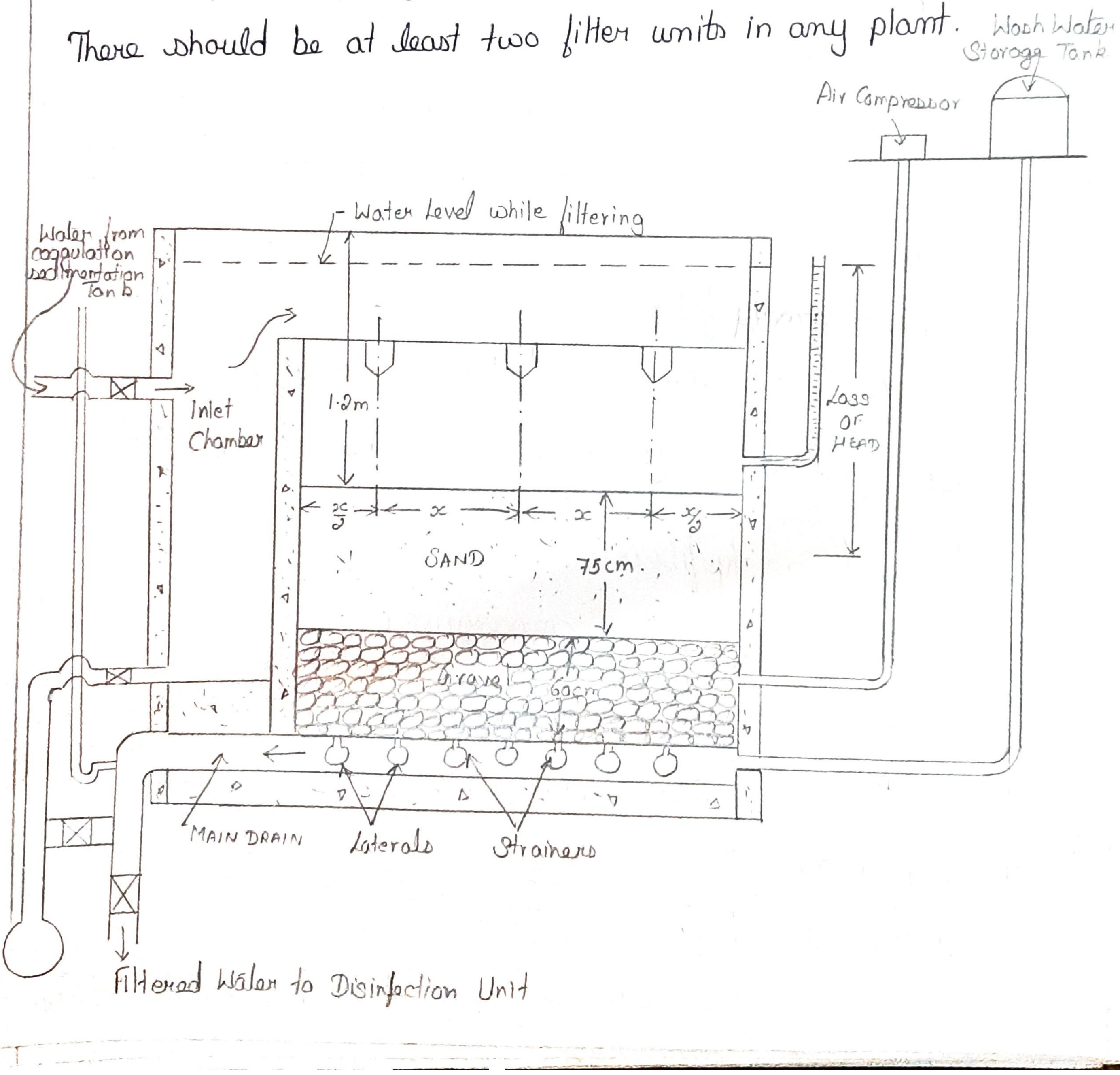
- The depth of the tank may vary from 2.5 to 3.5 m
- The area of the filter units should not be kept larger and is generally limited to about 10 to 80 m^2 for each unit.
- The number of units at a filter plant may be estimated by the equation developed by Morrell & Wallace

$$N = 1.22\sqrt{Q}$$

Where, N = no of filter units

Q = plant capacity in million litres per day.

There should be at least two filter units in any plant.



② Filter Media:

It consists of sand layers, about 60 to 90cm in depth, and placed over a gravel support.

The effective size of the sand varies from 0.35 to 0.5 mm & the uniformity coefficient ranges between 1.3 to 1.7.

③ Base Material:

- The base material is gravel, and it supports the sand.
- It also distributes the wash water.
- It consist of 60 to 90cm thick gravels of different sizes, placed in layers.
- Generally, five to six layers, each of 10 to 15 cm in depth are used.
- The coarsest gravel (about 40mm in size) is used in the bottom most layer and the finest gravel (about 3mm in size) is used in the top most layer.
- Size of gravel at the bottom most layer - 20 to 40mm
- Intermediate layer, between 12 to 20 mm and 6 to 12mm.
- Top most layer between 3 to 6mm.

④ Under-Drainage System:

It serves two purpose

1) To receive and collect the filtered water
2) To allow backwashing for cleaning of filter.

- Various forms of under-drainage systems are
  1) Manifold and lateral system
  2) The Wheeler bottom
  3) The porous plate bottom.

6) Other Appurtenances:
   (i) Wash water troughs
   (ii) Air compressor
   (iii) Rate Controller
   (iv) Miscellaneous accessories.

(i) Wash water troughs: The dirty wash water which comes out of the filter after cleaning it, is collected in wash water troughs or gutters & carried to the main gutter. These gutters may be square V-shaped or semi circular.

(ii) Air Compressor: During back washing the filter, the sand grains are agitated either by water jet, or by copressed air, or by mechanical racks. When compressed air is used, air compressor unit having the required capacity must be installed.

(iii) Rate Controller: In order to obtain automatically, a uniform rate of filtration irrespective of the head loss through the filter, rate controllers are required to be fitted at the outlet end of each filter unit.

(iv) Miscellaneous Accessories: Other devices such as head loss indicators, meters for measuring rate of flow, etc., are also needed.

Operational Troubles in Rapid Gravity filters:
1) Formation of mud balls
2) Cracking of filters

Uses of Rapid Gravity Filters:

1) They are best and most economical and used for treating water supplies, for large towns & cities.

Problem:

1) Design the approximate dimensions of a set of rapid gravity filters for treating water required for a population of 50,000; the rate of supply being 180 litres per day per person. The filters are rated to work 5000 litres per hour per sq.m. Assume whatever data are necessary, and not given.

Solution:

Assume that the given rate of supply is an average demand, and also assuming that the max. daily demand is 1.8 times the average daily demand, we have, by ignoring wash water requirements

The maximum water demand per day

= Population x Max. daily rate of supply

$= 50{,}000 \times 1.8 (180)$

$= 16.2 \times 10^6$ litres

= 16.2 million litres

Water demand per hour (ignoring time lost in cleaning)

$= \frac{16.2 \times 10^6}{24}$ litres/hr $= 675 \times 10^3$ litres/hr

Rate of filtration = 5000 l/hr/sq.m

∴ Area of filter beds required

$$= \frac{\text{Water demand}}{\text{Rate of filtration}}$$

$$= \frac{675 \times 10^3}{5000} \text{ sq.m}$$

$$= 135 \text{ sq.m}$$

Since two units are required to be designed

The area of each unit $= \frac{135}{2} = 67.5$ sq.m

Assuming $L = 1.5B$ we have

$$1.5B^2 = 67.5$$

$$B^2 = 45 \text{ or } B = 6.75\text{m}$$

Choose 6.75 m width and 10 m length. Hence two units of size 10 m x 6.75 m are required. One additional unit as stand by may also be provided for breakdowns, repairs, or cleaning operations.

Pressure Filters:

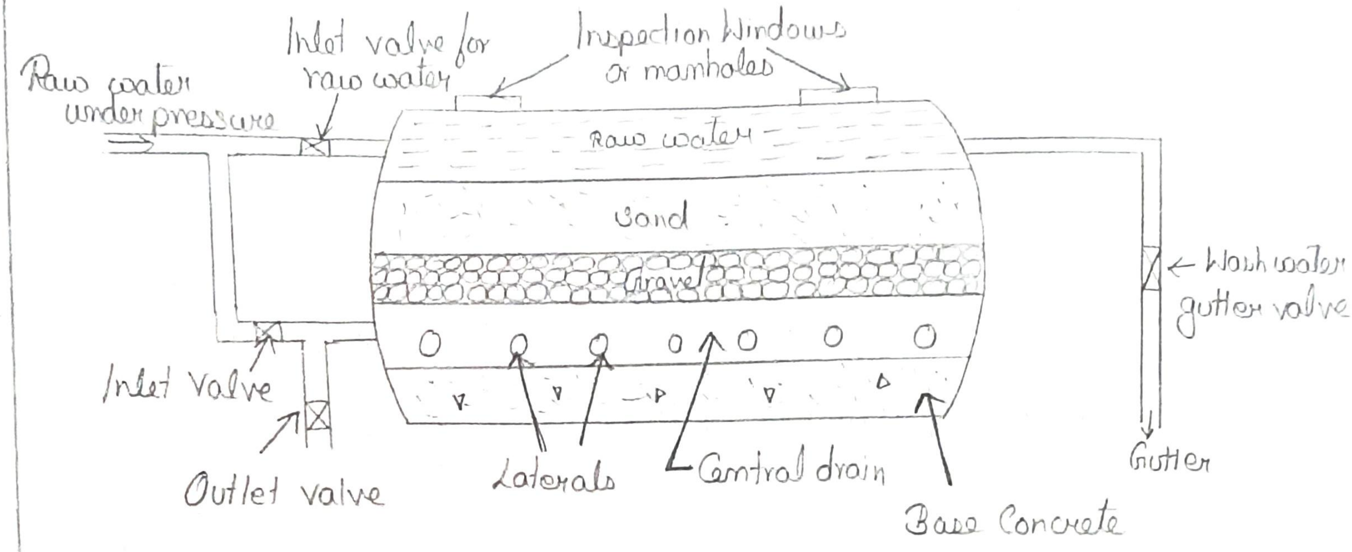
They are like small rapid gravity filters placed in closed vessels, through which the water to be treated is passed under pressure.

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.

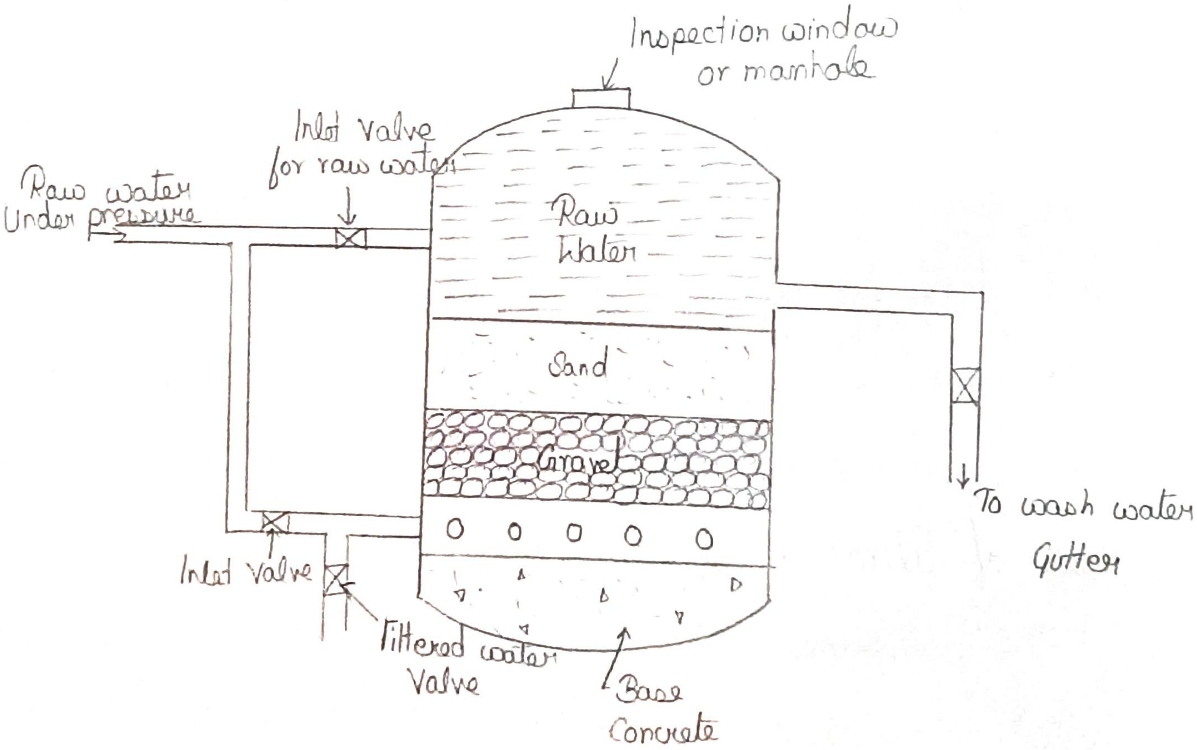
The raw water is pumped into the vessel by means of pumps.

- The pressure so developed may normally vary between 30 to 70 m head of water, i.e., 300 to 700 kN/m².

Construction



a) Horizontal Pressure filter



b) Vertical Pressure filter

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

- Steel cylinders are used as pressure vessel and may be rivetted or welded.
- Their diameter generally vary between 1.5 to 3m, and their lengths or heights may vary from 3.5 to 8m.
- Inspection windows are placed at top for inspection purposes.

Working of Pressure Filters:

- It 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 filters itself.
- The cleaning of the filter may be carried out by backwashing as it is done for normal rapid gravity filter.
- The filters are cleaned when the loss of head due to clogging, exceeds a certain fixed value.

Rate of filtration of Pressure filters:

- The pressure filters 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 of filtration normally ranges between 6,000 to 15,000 litres per hour per sq.m of filter area

Efficiency and Suitability of Pressure Filters:

The pressure filters are less efficient than the rapid gravity filters, in removing bacteria & turbidities.

The quality of their effluent is poorer & they are generally not used for public supplies.

Advantages:

1) A pressure filter is a compact machine and can be handled easily.

2) It requires lesser space and lesser filtering materials.

3) Sedimentation and coagulation tanks are avoided.

4) They are more flexible.

Disadvantages:

1) The rate of filtration is high, but the filter unit being smaller, the overall capacity of the plant is small.

2) Less efficient in removing bacteria & turbidities.

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

4) Inspection, cleaning and replacement of sand, gravel and under drainage system is difficult.

Disinfection:

The filtered water which is obtained either from the slow sand filters or rapid gravity filters, may normally contain some

harmful diseases producing bacteria in it.
- These bacteria must be killed in order to make the water safe for drinking.
- The chemicals used for killing these bacteria are known as disinfectants, & the process is known as disinfection or sterilisation.
- This process of purification is the most important, because the bacterially contaminated waters may lead to the spread of various diseases and their epidemics, thus causing disaster to public life.
- The disinfection not only removes the existing bacteria from the water at the plant, but also ensures their immediate killing even afterwards, in the distribution system.
- Chlorine has been found to be the best and the most ideal disinfectant and is now invariably used.

Minor methods of disinfection:

The following are the minor methods of disinfection:

1) Boiling of water
2) Treatment with excess lime.
3) Treatment with ozone
4) Treatment with iodine and bromine
5) Treatment with ultra-violet rays
6) Treatment with potassium permanganate
7) Treatment with silver, called Electra-Katadyn Process

Chlorination:

- Chlorine in its various forms is invariably and almost universally used for disinfecting public water supplies.
- It is cheap, reliable, easy to handle, easily measurable, & is capable of providing residual disinfecting effects for long periods.
- The only disadvantage is that when used in greater amounts, it imparts bitter & bad taste to the water.

Disinfecting action of chlorine:

When chlorine is added to water, it forms hypochlorous acid or hypochlorite ions, which have an immediate and disastrous effect on most forms of microscopic organisms. The reactions that takes place are

$$Cl_2 + H_2O \xrightarrow{pH > 5} \underset{\text{Hypochlorous acid}}{HOCl} + HCl$$

The hypochlorous acid is unstable and may break into hydrogen ions & hypochlorite ions

$$HOCl \underset{pH < 7}{\overset{pH > 8}{\rightleftharpoons}} \underset{\text{Hydrogen ions}}{H^+} + \underset{\text{Hypochlorite ions}}{OCl^-}$$

The above reaction is reversible and depends upon the pH value of water.

Doses of Chlorine :

The amount of chlorine required for a water depends upon the inorganic and organic impurities present in it, because when chlorine is added to a water, it first of all reacts with the inorganic impurities that converts the chlorine into Chlorides, which has no residual oxidising power.

Excess chlorine after this point is consumed by ammonia to form chloramines.

Simultaneously, chlorine will also react with organic impurities present in water.

The chlorine consumed in the above reactions represents the chlorine demand of water. When once it gets satisfied, the chlorine will appear as free chlorine.

The optimum dose of Chlorine for a given water is determined experimentally by adding various amounts of chlorine to a given sample and observing the residual left after a contact period of about 10 minutes.

The dose which leaves a residual of about 0.2 mg/l is then selected.

This total dose (in mg/l) minus the free residual will automatically represent the chlorine demand of water.

The chlorine dose must generally be increased during rainy season and epidemics.

Various Forms of Chlorine:

1) As free chlorine

- In the form of liquid chlorine or as chlorine gas

2) As combined Chlorine:

- In the form of hypochlorites or bleaching powder
- In the form of Chloramines (Mixture of ammonia & Chlorine)
- In the form of chlorine dioxide.

Types of Chlorination:

Depending upon the quantity of chlorine added, or the stage at which it is added, or upon the results of chlorination. They are

1) Plain Chlorination:

The term is used to indicate that only the chlorine treatment and no other treatment has been given to the raw water.

2) Pre Chlorination:

It is the process of applying chlorine to the water before filtration or rather before sedimentation coagulation.

3) Post Chlorination:

It is the normal standard process of applying the chlorine in the end, when all the other treatments have been completed.

4) Double Chlorination:

It is used to indicate that water has been chlorinated twice. The pre-chlorination & post-chlorination are generally use in double chlorination.

5) Break-point Chlorination:

It represents that much dose of chlorination, beyond which any further addition of chlorine will appear as free residual chlorine

6) Super Chlorination:

It is the term which indicates the addition of excessive amount of chlorine to the water.

7) Dechlorination:

It is meant as removal of chlorine from water.

Testing of Chlorine residuals:

It can be experimentally determined by using the following methods

1) Orthotolidine test
2) D.P.D test
3) Chlorotex test &
4) Starch Iodide Test

Aeration:

- Under this process, water is brought in intimate contact with air, so as to absorb oxygen and to remove carbon dioxide gas.
- It also helps in killing of bacteria to a certain extent, removing of H_2S gas and iron and manganese to a certain extent, from the treated water.
- The aeration of water can be carried out in one of the following ways

1) By using Spray Nozzles:
- The water is sprinkled in air or atmosphere through special nozzles which breaks the water into droplets, thus permitting the escape of dissolved gases.
- Carbon dioxide upto 90% is removed in this process.

2) By permitting water to trickle over cascades:
- The water is made to fall through a certain height (1 to 3m) over a series of steps (three to ten) with a fall of about 0.15 to 0.3 m in each step. The structure so formed is called freefall aerator.
- The simplest form of a freefall aerator is known as a cascade aerator.
- The aerator should preferably be installed in open air.
- The cascade aerator are efficient in raising dissolved oxygen content of water, but not for CO_2 removal, which is removed

only in the range of 60 to 70 %

3) By air diffusion:

- In this method, compressed air is bubbled through the water, so as to thoroughly mix it with water.

- Perforated pipes are installed at the bottom of the settling tank and the compressed air is blown through them.

- 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.

4) By using trickling filters:

- The water is allowed to trickle down the beds of coke, supported over the perforated bottomed trays & arranged vertically in series.

- Generally three beds are used, the depth of each being about 0.6 m with a clear distance of 0.45m in between.

- The water is applied from the top through perforated distribution pipes & allowed to trickle down, upto the bottom bed.

- During this downward movement, the water gets mixed up with air & aeration takes place

- The size of the coke to be used usually ranges between 50 to 75 mm.

33)

Aeration should, be used only to a limited extent because too much of absorbed oxygen will make the water corrosive & may neccessiate the deaeration process.

(1)

UNIT-IV

ADVANCED WATER TREATMENT

Water Softening:

- The reduction or removal of hardness from water is known as water softening.
- It is not essential to soften the water in order to make the water safe for public uses.
- The advantage of softening lies chiefly in the reduction of soap consumption, lowered cost in maintaining plumbing fixtures, and improved taste of food preparation.
- Hence, whether or not the hardness of a water supply should be reduced, depends on the relation between the cost of treatment and the obtained resultant saving and satisfaction to the consumers.
- However, for industrial supplies, the softening is more important, because the hard waters are likely to cause scaling troubles in boilers and interfere in the working of dyeing systems.

Methods of removing temporary Hardness:

(1) Boiling:

- Calcium carbonate, being only slightly soluble, will usually exist in water as calcium bicarbonate, because it easily dissolves in water containing carbon dioxide.

- When such water is boiled, the carbon dioxide gas will get out, leading to the precipitation of $CaCO_3$, which can be sedimented out in settling tank.

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

Calcium bicarbonate — Calcium Carbonate Insoluble

- The Magnesium bicarbonate and magnesium carbonate, cannot be satisfactorily removed under the above type since it is fairly soluble in water.

- Boiling cannot therefore satisfactorily remove the temporary hardness caused by magnesium.

(2) Addition of Lime:

- Lime (CaO), generally hydrated lime [$Ca(OH)_2$] is added to the water. The following reactions takes place

i) $MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow + CaCO_3 \uparrow$

Magnesium Carbonate — Hydrated Lime — Magnesium Hydroxide (insoluble) — Calcium Carbonate (Insoluble)

ii) $Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Ca(HCO_3)_2 + Mg(OH)_2 \downarrow$

Magnesium bicarbonate — Hydrated Lime — Magnesium Hydroxide

iii) $Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 \downarrow + 2H_2O$

Calcium bicarbonate

- The calcium carbonate and magnesium hydroxide are precipitated and can be removed in the sedimentation tank.

- This method is generally adopted for softening waters which contains only temporary hardness.

Methods of Removing Permanent Hardness:

- The permanent hardness is more permanent & dificult to remove.

- It can however, be removed by certain special methods, generally called water softening methods.

- The three methods adopted are

1) Lime - Soda process
2) Base - Exchange Process (or) Zeolite process
3) Demineralisation Process

① Lime - Soda Process for Removing Hardness:

- In this process, lime [$Ca(OH)_2$] and soda ash [Na_2CO_3] are added to the hard water; which reacts with the calcium & magnesium salts, so as to form insoluble precipitates of calcium carbonate & magnesium hydroxide [$Mg(OH)_2$].

- These precipitates can be sedimented out in a sedimentation tank.

- The chemical reactions which may be involved are

(4)

i) $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$

Carbonate hardness of Ca — Lime

ii a) $Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow Ca(HCO_3)_2 + Mg(OH)_2 \downarrow$

Carbonate hardness of Mg — Lime

ii b) $MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaCO_3 \downarrow$

Carbonate hardness of Mg — Lime

iii) $MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaCl_2$

Non-carbonate hardness of Mg — Lime — Non-carbonate hardness of Ca.

iv) $MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaSO_4$

Non-carbonate hardness of Mg — Lime — Non-carbonate hardness of Ca

v) $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + H_2O$

(Free dissolved CO_2) — Lime

vi) $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl$

Non carbonate hardness of Ca — Soda

vii) $CaSO_4 + Na_2SO_4 \rightarrow CaCO_3 \downarrow + Na_2SO_4$

Non carbonate hardness of Ca — Soda

From the above reactions, it can be easily seen that lime helps in removing the entire carbonate hardness (i.e, the carbonate hardness caused by Ca as well as that caused by Mg), & it reacts with non-carbonate hardness of Mg to convert the same into non carbonate hardness of Ca.

- The non carbonate hardness is finally removed by soda.
- The Sodium salts which are finally formed in the above method, are soluble in water, but are generally not objectionable in the amount resulting from softening process.
- Most of the calcium carbonate and magnesium hydroxide which is formed get precipitated and can be sedimented out in the sedimentation tank.
- The little quantity which remains as finely divided particles, causes deposition on the filter & leads to enlargement of the sand grains called incrustation of filter media.
- To prevent this, it is generally necessary that the water be recarbonated by passing CO_2 gas through it, as it leaves the sedimentation tank.
- In the **recarbonation** process, the insoluble carbonates combine with the carbon dioxide to again form the soluble bicarbonates, as given below

(i) $CaCO_3 \downarrow + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$

Insoluble Calcium Carbonate → Soluble Calcium bicarbonate

ii) $Mg(OH)_2 + CO_2 \longrightarrow MgCO_3 + H_2O$

$MgCO_3 + CO_2 + H_2O \longrightarrow Mg(HCO_3)_2$

- The amount of lime and soda required for the softening, depends upon the chemical quality of water and the extent of hardness removal desired.

- The equipment required for the lime soda treatment is similar to that required for chemical coagulation.

- However, for obtaining good results, the detention time for settling basin may be kept slightly more, varying between 2 to 4 hours.

- The water coming out from the sedimentation tank is then passed through a recarbonation plant.

- The effluents from the recarbonation plant are finally passed through a rapid gravity filter.

Advantages:

1) The process is economical

2) Easily combined with the usual water treatment methods, without extra trouble or cost.

3) When lime & soda are added in addition to the coagulants, during the process of softening-cum-coagulation, lesser quantity of coagulant is generally required.

4) It increases the pH value of water thus reducing the corrosion of the distribution pipes.

5) Helps in reducing total mineral content of water.

Disadvantages:

1) A large quantity of sludge is formed in this process which

must be disposed off by suitable methods.
2) Careful operation and skilled supervision is required in order to get good results.
3) Incrustation of pipe walls of the distribution system will result, if the water is not properly recarbonated.
4) This process cannot help in producing waters of zero hardness.

(2) Zeolite (or) Base-Exchange (or) Cation-Exchange Process

- The zeolites or Resins have the excellent property of exchanging their cations, & hence, during softening operation, the sodium ions of the zeolite get replaced by the calcium & magnesium ions present in hard waters.

- The chemical reactions which may be involved are given in the following equation, where Z stands for the complex zeolite radical.

$$Na_2Z + \begin{matrix} Ca \\ Mg \end{matrix} \begin{cases} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{cases} \longrightarrow Na_2 \begin{cases} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{cases} + \begin{matrix} Ca \\ Mg \end{matrix} \Big\} Z$$

The calcium and magnesium zeolite can be regenerated into active sodium zeolite by treating it with 5-10 per cent solution of sodium chloride.

The exchange reactions that take place during regeneration can be represented as

$$\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Z + 2NaCl \longrightarrow Na_2Z + \left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Cl_2$$

Used zeolite — Sodium Chloride Solution — Regenerated Zeolite.

A zeolite softeners resembles a sand filter in which the filtering medium is a zeolite rather than sand.

The hard water enters through, the top, and is evenly distributed on the entire zeolite bed.

The softened water is collected through the strainers at the base.

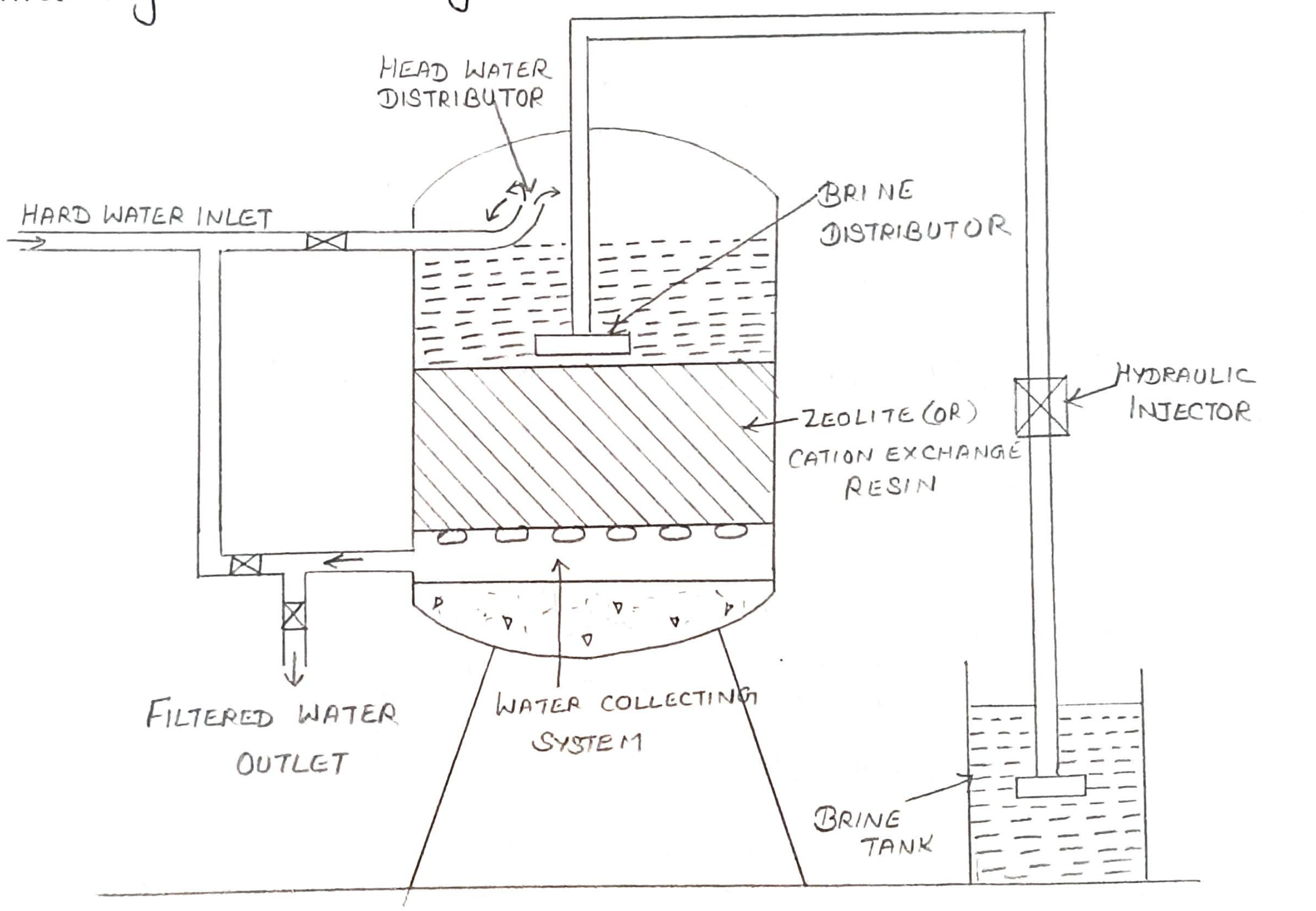
- When a significant portion of the sodium in the zeolite has been replaced by calcium & magnesium, it is regenerated by first washing it with water by reversing the flow, and then treating it with 10 percent solution of brine.
- The excess brine solution retained in the zeolite after the treatment is removed by again washing it with good water.
- The regenerated zeolite can be used afresh for softening.
- The rate of filtration through a zeolite softener is about 300 litres per sq.m per minute.

Advantages:

1) Water of zero hardness can be obtained, & hence, useful for specific uses in textile industries, boilers, etc
2) The plant is compact, automatic, & easy to operate.

3) No sludge is formed
4) The Running, maintenance and operation cost is quite less.
5) It removes ferrous iron & manganese from water

Disadvantages:
1) The process is not suitable for treating highly turbid waters.
2) The process leaves sodium bicarbonate in water, which causes priming & foaming in industrial or boiler feed waters.
3) The zeolite process is costlier & unsuitable for treating waters containing iron & manganese.



③ Demineralisation Process for removing hardness
- It is the process of removing the minerals from water.
- This process helps in completely removing or reducing the

mineral content by any desired extent, it is very suitable for producing water of any desired hardness or even mineral free water.

- This demineralised water, sometimes called deionised water, is as pure as distilled water, & is very suitable for industrial purposes, especially for steam raising in high pressure boilers.

- This complete removal of minerals present in water can be carried out by first passing the water through a bed of cation exchange resins, & then through a bed of anion exchange resins.

- The process of passing the water through cation exchange resins produces similar effects as in zeolite method, except that hydrogen is exchanged for the basic metallic ions.

- The chemical reactions involved during the process may be represented as

$$Ca(HCO_3)_2 + H_2R \longrightarrow CaR + 2H_2O + 2CO_2 \uparrow$$

(H_2R: Fresh Cation Exchange Resin; CaR: Exhausted Resin)

$$CaCl_2 + H_2R \longrightarrow CaR + 2HCl$$

$$MgSO_4 + H_2R \longrightarrow MgR + H_2SO_4$$

$$2NaCl + H_2R \longrightarrow Na_2R + 2HCl$$

- The water coming out of the cation-exchanger will now contain diluted carbonic acid, hydrochloric acid, sulphuric acid, etc (instead of originally present minerals & salts), & can be removed by passing the water through a bed of anion exchange resin.

- The anion-exchange resins are formed by the condensation of amines with formaldehde & capable of replacing the anions with their hydroxyl ions.

- The chemical formula for such a resin may be written as ROH, where OH represents the hydroxyl ions & R represents the organic part of the substance.

- The chemical formula that may be involved are

$$ROH + HCl \longrightarrow RCl + HOH$$

Fresh anion exchange resin → Exhausted resin, Water

$$2ROH + H_2SO_4 \longrightarrow R_2SO_4 + 2HOH$$

Fresh anion exchange resin → Exhausted resin, Water

- The water coming out from this anion exchanger will then be free from minerals.

- The extent of removal will depend upon the strength & freshness of the resins used.

- The completely dimineralised water can sometimes be added to raw water, so as to obtain the resultant supplies of any desired mineral content

Regeneration of cation exchange resins:

- The exhausted cation exchange resins can be regenerated by treating with dilute hydrochloric acid or sulphuric acid.

The reactions likely to take place are

$$\left.\begin{matrix}Ca\\Mg\\Na_2\end{matrix}\right\} R + 2HCl \longrightarrow H_2R + \left.\begin{matrix}Ca\\Mg\\Na_2\end{matrix}\right\} Cl_2$$

Exhausted cation exchange resin → Regenerated cation exchange resin from

$$\left.\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right\} R + H_2SO_4 \longrightarrow H_2R + \left.\begin{matrix} Ca \\ Mg \\ Na_2 \end{matrix}\right\} SO_4$$

Exhausted cation exchange resin — Regenerated cation exchange resin.

Regeneration of anion-exchange resin:

The exhausted anion exchange resins can be similarly regenerated by treating them with sodium carbonate solution. The likely reaction will be

$$RCl + Na_2CO_3 + 2H_2O \longrightarrow 2ROH + 2NaCl + CO_2\uparrow + H_2O$$

Exhausted anion resin — Regenerated anion resin

Desalination:

The process of removing salt from water is known as desalination, & the resultant water which is free from salt is known as fresh water.

Classification of Salty Water:

S.No	Type of Water	TDS value in mg/l
1.	Sweet waters	0-1000
2.	Brackish waters	1000 - 5000
3.	Moderately Saline Water	5000 - 10,000
4.	Severely Saline water	10,000 - 30,000
5.	Sea water	Above 30,000.

Cost Aspects of desalination:

- Desalination is a costly process.
- The water obtained by desalination proves much costlier than the naturally available treated water.
- With modern equipments, the cost of producing fresh water

from sea water has been reduced to about seven times.

Methods of Desalination:

(1) Desalination by evaporation & distillation
(2) Electrodialysis method
(3) Reverse osmosis method
(4) Freezing process
(5) Solar distillation method
(6) Other methods.

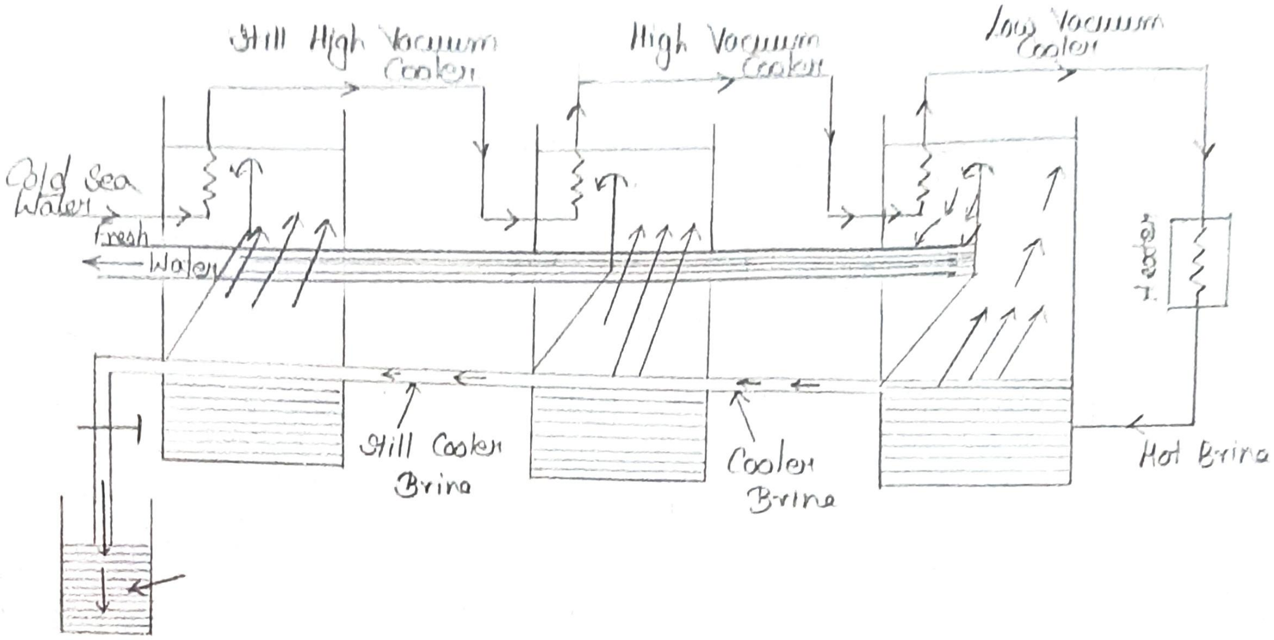
(1) Desalination by evaporation & distillation:

- Sea waters is boiled in giant stills called evaporators, & the vapour produced is caught & condensed into fresh water.
- A modern salt water 'evaporator' works on the principle of a 'still', but it is more efficient.
- In its simplest form it consists of a metal box in which the salt water is heated by a nest of pipes, carrying very hot steam.
- Heat passes from the steam through the pipe walls & boils the brine.
- The boiling brine nest of pipes, filled with cold brine, condenses it to fresh & pure water.
- The heat coming out from the vapour, during cooling operation, warms the cold brine, which is then sent to the evaporator

Multi-Stage Evaporator: Water is forced to evaporate & condense again & again in various stages.

These modern evaporators throw away very little heat energy

- They use it again & again by 'Staging' the evaporator, until it is so low in temperature that is too week to be useful.

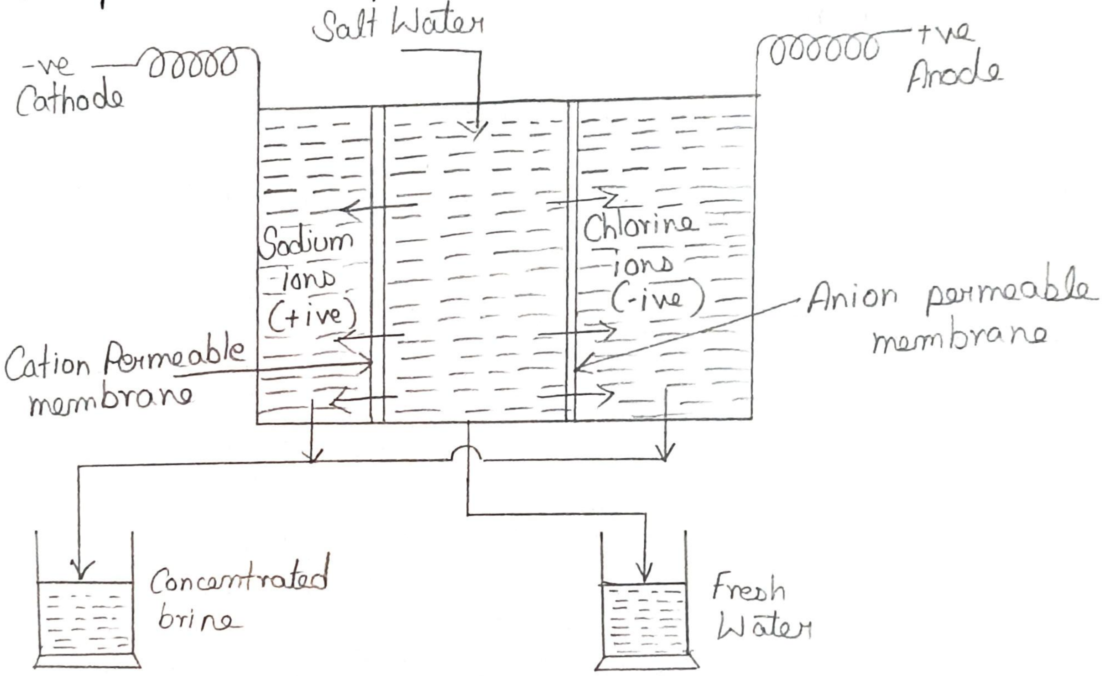


② Desalination by Electrodialysis method:

- In salt water, H_2O molecules are bonded together with the sodium and chlorine ions.
- These hydrogen-bonds between the H_2O molecules & Na^+ and Cl^- ions must be broken up, in order to seperate the salt from water.
- In this method these bonds are broken with the help of electricity.
- If an electric current is passed through the salt-solution, the sodium and chlorine ions gets freed from water molecules, & they start moving towards their oppositely charged electric poles.
- The positively charged sodium ions will move towards the negative pole i.e., cathode and the negatively charged chlorine ions will move towards the positive pole, i.e., anode.
- If these cations & anions are allowed to segregate in different compartments, what is left is fresh water.

until

- The segregation is achieved by means of thin plastic like sheets called membranes.
- They are made of peculiar chemical substances called "ion exchange resins' and they are very very thin, say about 1/180th of a cm.
- These thin membranes can be economically made & have the ability to accept or reject certain molecules in solution.
- By choosing the right kind of resin, membranes could be made that would pass either positive or negative ions but not both.



Advantages:

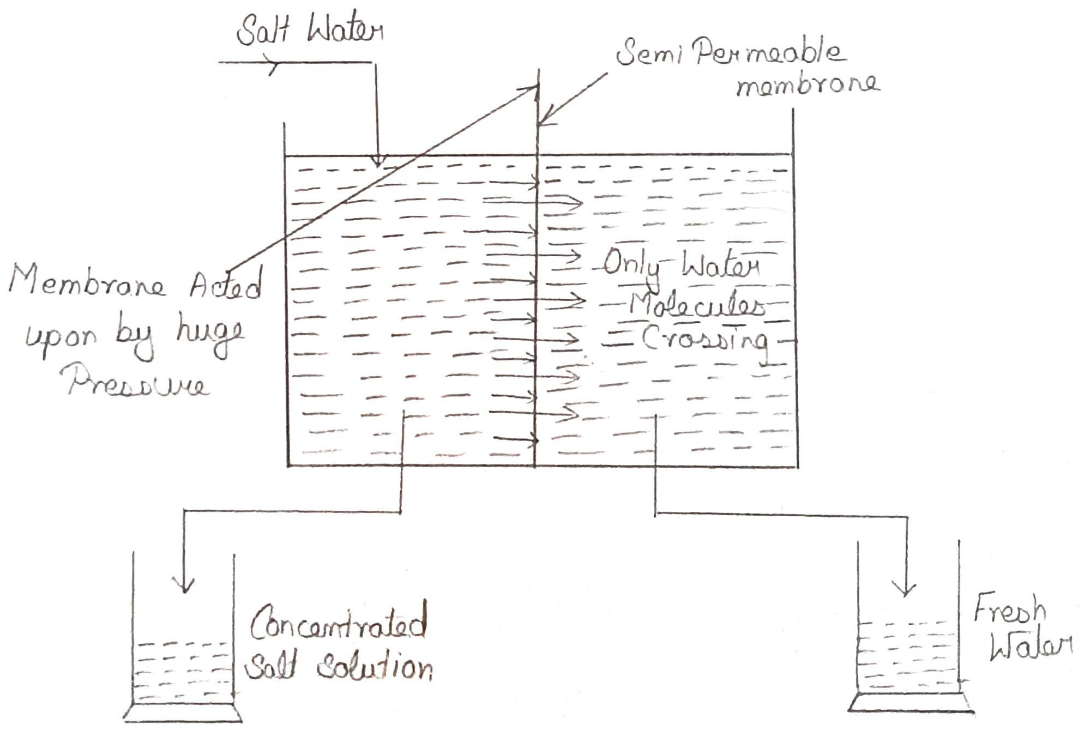
1) When too much of purification is not required, this method is the best of all the available methods.
2) It is a compact machine
3) The cost of buying & erecting the plant is small.
4) It is easy to operate

③ Desalination by Reverse Osmosis process:

In this method, the water molecules and the salt ions are seperated by forcing the salt solution against a 'semi-permeable membrane' barrier, which permits the flow of water through itself but stops the salt.

In ordinary osmosis when salt solution is seperated from pure water by a semipermeable membrane, the pure water flows across the membrane until the pressure on the pure water side become equal to the osmotic pressure of the salt solution.

In reverse osmosis process, the natural osmotic pressure is opposed by exerting an external pressure on the side containing the salt solution.



The osmotic pressure is proportional to the TDS of the water and a pressure of atleast twice the osmotic pressure is required to achieve an economically feasible flow.

The semi-permeable membrane used in this process is thin but dense and strong enough to withstand the high external pressure.

It is supported by a grid, and the salty water circulates against one surface of it.

This surface has a thick & tough skin, while the body of the membrane is softer & less dense.

Reverse Osmosis does not work below 60,000 kN/m² & is usually operated at about 1,00,000 kN/m².

Pressure driven processes can be broadly classified according to the membrane pore size and size of particles removed

These processes are

i) Microfiltration (MF)
ii) Ultrafiltration (UF)
iii) Nanofiltration (NF) &
iv) Reverse osmosis (RO)

④ Desalination by Freezing Process:

This method is based upon the principle that when salt water freezes, the ice formed in the beginning is almost free from salt.

This ice, when melted, can give good water.

- The quality of water obtained is satisfactory, but the cost o production is high & prohibitive

(5) Desalination by Solar distillation method:

Solar heat is a free heat, & everyday the sun vaporises billions of tonnes of sea water & lifts vapour into clouds. If this vapour can be caught & distilled to pure water, we can definitely get cheaper water.

Removal of Iron and Manganese from Water

- Iron and manganese salts are generally found dissolved together in well water or anaerobic reservoir water, in invisible dissolved state.

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

- When their concentration exceeds about 0.3 mg/l & 0.05 mg/l respectively, they become objectionable due to the following reasons

i) They cause discolouration of clothes washed in such waters due to deposition of red/brown coloured oxides of iron/ manganese.

ii) They cause incrustation of the water-mains due to deposition of ferric hydroxide & manganese oxide.

iii) They make the water unpleasant in taste

iv) The reduced Iron in water promotes the growth of autotrophic bacteria in distribution mains.

- The iron & manganese may be present in water either in combination with organic matter or without such combination.

- When present without combination with organic matter, they can be easily removed by aeration, followed by coagulation, sedimentation & filtration.

- During aeration, the soluble ferrous and manganous compounds present in the water may get oxidized into insoluble ferric & manganic compounds, which can be sedimented out easily.

- On the other hand, when iron and manganese are present in combination with organic matter, it becomes difficult to break the bond between them & to cause their removal. However, when once this bond is broken, they can be removed.

- This bond may be removed by adding lime, & increasing the pH value of matter to about 8.5 to 9; or by adding chlorine or potassium permanganate.

- Manganese zeolite, a natural green sand, coated with manganese dioxide, can also be used for removing soluble iron & manganese from solution.

Addition and Removal of Fluorides from water

① Flowridation:

- Flowrides are added to waters found deficient in fluoride concentration, under a process known as flowridation.

- It is done when the fluoride concentration is less than an optimum value of about 1mg/l.

- Scarcity of flowride in consumed water, may lead to formation of weaker tooth enamel leading to early tooth decay.

- It proves beneficial to older people in reducing hardening of arteries, stimulates bone formation, helpful in treatment of osteoporosis.

② Deflowridation:

When the flowride concentration in a given water exceeds the limiting value of 1 to 1.5 mg/l, the fluorides are removed under a process known as deflowridation.

Excess intake of fluoride can lead to dental fluorosis, skeletal fluorisis, or non-skeletal fluorisis.

Skeletal fluorisis leads to severe and permanent bone & joint deformations.

Dental fluorisis is characterized by discoloured, blackened mottled or chalky white teeth.

- Non skeletal fluorisis leads to gastro-intestinal problems and neurological disorders.
- Fluorisis is an irreversible disease and it has no cure.

Methods of Defluoridation:

1) Adsorption by Activated Alumina
2) Ion Exchange Adsorption
3) Nalgonda Technique
4) Reverse Osmosis Process

① Adsorption by Activated Alumina

The raw water containing high contents of fluoride, is passed through the insoluble granular beds of substances like Activated Alumina, or Bone Char, or activated carbon; which adsorbs fluoride from the percolating water, giving out defluoridated water.

Activated Alumina found to be an excellent medium for removal of excess fluoride.

It is highly selective to fluoride in the presence of sulphates and chlorides, when compared to synthetic ion exchange resins.

In the presence of bicarbonates, although the fluoride level is reduced, the absorption capacity shows a major decline.

Silica is known to interfere with the adsorption of fluoride.

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

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

② Ion Exchange Adsorption Method:

The ion exchange process is almost similar to that for removing hardness from water.

The process uses a strong base anion exchange resin in the chloride form.

As the water passes through the bed of the resin contained in a pressure vessel, fluorides, and other anions like arsenic, nitrates etc., present in the water are exchanged with the chloride ions of the resin, thus releasing chlorides into the water and absorbing flourides ions into the resin.

The arsenic and nitrate ions also get removed in the process.

When the resins gets saturated with anions like flouride, nitrate, arsenic, etc as indicated by their increased concentration in the out flowing water, the same can be cleaned & regenerated with 5 to 10% sodium chloride solution (brine), & the bed is returned to service.

- To ensure that a flow is maintained during regeneration, ideally 100% standby units should be provided.
- The capacity of a plant based on this technology may range from 500 l/h to 5000 l/h.
- Although the method ensures high efficiency of fluoride removal yet it requires regular replacement of resin, and large amount of salt (NaCl) for regeneration of resins saturated with flourides.
- This method is found to be very costly and good after sales service in villages do not become easily available.
- The safe disposal of waste water from regeneration, containing high concentrations of toxic flouride, nitrate and arsenic ions, etc again possess serious problems.

③ Nalgonda Technique:

This technique is found to be simpler and economical than fixed bed ion exchange processes, since it does not involve regeneration of media, and employs chemicals which are readily available, and easy to operate & maintain using local skills.

It also helps in removal of colour, odour, turbidity, bacteria & organic contaminants from raw supplies.

It uses aluminium salt (alum) for removing flouride.

The 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

④ Reverse Osmosis Process:

The raw water is passed through a semi permeable membrane barrier, which permits the flow of clear water through itself & blocks the flow of salts including fluorides.

This method is rarely used solely for deflouridation of village water supplies due to prohibitive high cost and poor after sales service of machines.

RO Reject Management:

RO reject water disposal is commonly used to purify drinking water and desalinate seawater to yield potable water

The water and other molecules with lower molecular weight pass through the micropores in the membranes, yielding a purified water stream called the permeate.

Larger molecules are retained by the membranes as well as a portion of the water that does not pass through the membranes.

Construction of Water Treatment Plants:

- They are constructed by concrete or masonry and medium to large size treatment plants are largely made of reinforced concrete.
- The structures must be water tight.
- Some parts of the piping system like bends may be manufactured on site from steel pipes.
- Strict supervision is essential during construction so that quality control is maintained and any defects are detected & dealt timely.
- Rapid gravity sand filters must be closed & roofed to protect from sun, wind & dust.

Membrane Process:

A membrane is a thin layer of semi-permeable material that seperates substances when a driving force is applied across the membranes.

They are used for removal of bacteria, micro-organisms, particulates, & natural organic material, which can impart colour, tastes & odour to water.

① Microfiltration (MF):

It is defined as the membrane seperation process using membranes with a pore size of approximately 0.03 to 10 microns (1 micron = 0.0001 mm), a molecular weight cut off of greater than 10,00,000 Dalton's and a relatively low feed water operating pressure of approximately 100 to 400 kPa.

Materials removed by MF include sand, silt, clays, algae & some bacterial species.

When MF is used in combination with disinfection, MF appears to control these micro organisms in water.

By physically removing the pathogens, membrane filtration can significantly reduce chemical addition, such as chlorination.

MF removes little or no organic matter, however, when pre-treatment is applied, increased removal of organic material can occur.

MF can be used as a pre-treatment to RO or NF to reduce fouling potential.

③ Ultra filtration:

Ultra filtration has a pore size of approximately 0.002 to 0.1 microns, molecular weight cut off (MWCO) of approximately 10,000 to 1,00,000 Daltons, and an operating pressure of approximately 200 to 700 kPa.

UF will remove all microbiological species removed by MF, as well as some viruses and humic materials.

③ Nano - Filtration:

Nano filtration membranes have a nominal pore size of approximately 0.001 microns and MWCO of 1,000 to 1,00,000 daltons.

Pushing water through these smaller membrane pores requires a higher operation pressure than used in MF or UF.

Operating pressures are usually near 600 kPa and can be as high as 1,000 kPa.

These systems can remove virtually all cysts, bacteria, viruses and humic materials.

NF also removes hardness from water, which accounts for NF membranes sometimes being called "Softening membranes".

Hard water treated by NF will need pre-treatment to avoid precipitation of hardness ions on the membrane.

4) Reverse Osmosis:

It can effectively remove nearly all inorganic contaminants from water.

RO can also effectively remove radium, natural organic substances, pesticides, cysts, bacteria and viruses.

RO is particularly effective when used in series with multiple units.

Advantages:

1) Removes nearly all contaminant ions & most dissolved non-ions.

2) RO operates immediately, without any minimum break in period.

3) Low effluent concentration possible.

4) Bacteria and particles are also removed.

Disadvantages:

1) High capital and operating costs

2) High level of pre-treatment is required in some cases.

3) They are prone to fouling.

①

UNIT-V

WATER DISTRIBUTION AND SUPPLY

In order to fulfill the water requirements for domestic, industrial, and commercial purposes, a systemmatic arrangement is necessary.

The purified or treated water has to be distributed from the treatment units, to the individual houses.

A well planned distribution system consists of the arrangements of pipelines, valves, hydrants, service connection, service reservoirs and pumps, etc.,

The complete arrangement used to distribute the purified water to the consumers is called Water distribution System.

Requirements of water distribution system:

The various requirements for the proper functioning of a distribution system are

1) It should have the capability of supplying the water with adequate pressures.
2) The fire demand should be met out sufficiently.
3) Purity of water should be maintained.
4) It should be easy for operations and maintenance.

5) Cost for operation, maintenance and reinstallation should be minimum.

6) It should not make any disturbance to the surrounding nature.

7) It should be safe against all the possible causes of failure such as bursting of pipe lines, etc.,

Components of Water Distribution system:

Water distribution system in the system of network consists of,

1) Pipelines (for carrying waters)

   a) Supply Mains

   b) Sub Mains

   c) Branches

2) Valves (Controlling the flow of water in pipes)

   a) Sluice Valves

   b) Drain Valves

   c) Air Valves

3) Hydrants (Connections used to release the water at emergencies)

4) Pumps (for lifting and pressurizing the water inside pipes)

5) Distribution or service reservoirs (Storing the purified water to distribute)

Service Reservoirs:

They are the storage tanks used in Water Distribution system, used to store the required quantity of water, to provide storage for fire fighting and emergencies and to stabilize the pressure in the distribution network.

They may be constructed of brick masonry, stone masonry, PCC, RCC, prestressed concrete or steel.

It is included with all necessary arrangements for repair & maintenance.

Functions of Reservoirs:

1) Based on the hourly variations in demand, it directs the treatment units to operate at uniform rate

2) Reservoirs maintain the pressure of water in water mains.

3) They supply water during emergencies.

4) It increases the pressure considerably in the case of elevated reservoirs.

5) It reduces the overall cost reduction in pumping and makes the distribution system economical.

Types of Reservoirs:

Based on the location with respect to ground level, the storage reservoirs are classified as

1) Surface Reservoirs
2) Elevated Reservoirs

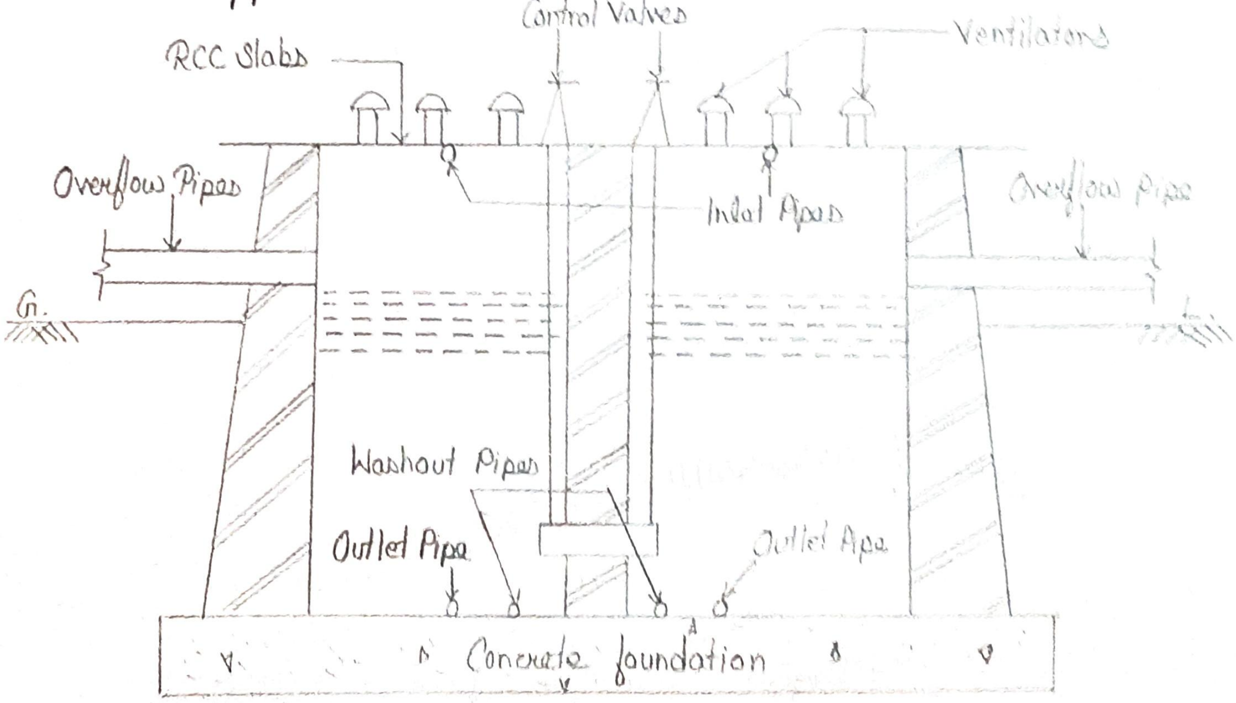
3) Stand Pipes

1) Surface Reservoirs:

They are circular or rectangular shaped water tanks located at ground level or below the ground surface. It is also called Ground (or) Non-elevated reservoirs.

In a gravitational type of distribution system, water is stored in the ground service reservoir and then directly sent from there into the distribution system.

In a combined gravity and pumping system of distribution, the treated water is first of all stored in a ground reservoir & then pumped into the elevated service reservoir from where it can be supplied into the distribution mains.



It is divided into two compartments, so that one may be cleaned and repaired while the other is in use.

- The two compartments are connected with each other by shut off valve or sluice valves.

- Overflow pipes are provided at fully supply level, so as to maintain a constant water level.

- Ventilators are provided in the roof slab for free circulation of air.

- Although the stored water is treated, yet some sludge may settle down due to storage, & hence has to be removed.

- Such a reservoir is cleaned through the wash out pipes, at suitable intervals.

- The outlet pipes are laid slightly at a higher level than that of the washout pipes.

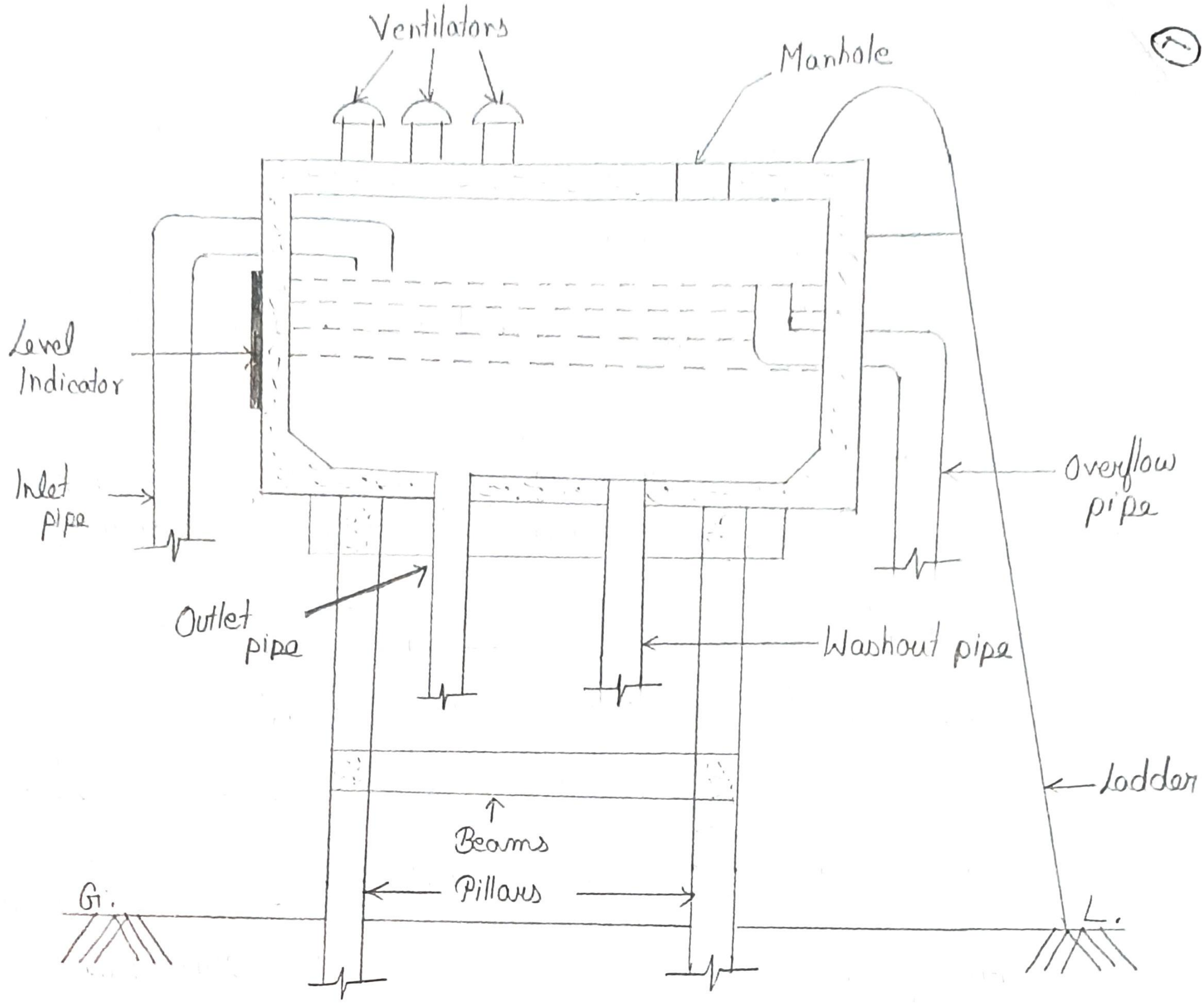
Elevated Reservoir:

- They are constructed above the ground level and supported on towers.

- These are rectangular, circular or elliptical overhead tanks erected at a certain suitable elevation above the ground level.

- These are constructed where the pressure is the main requirement and the water distribution may be carried out by gravity system after pumping and where stand pipes are not in use.

(6)



They are also located in areas where the combined gravity and pumping system for water distribution is adopted.

Water is pumped into these elevated tanks from the filter units or from the surface reservoirs, and then supplied to the buildings.

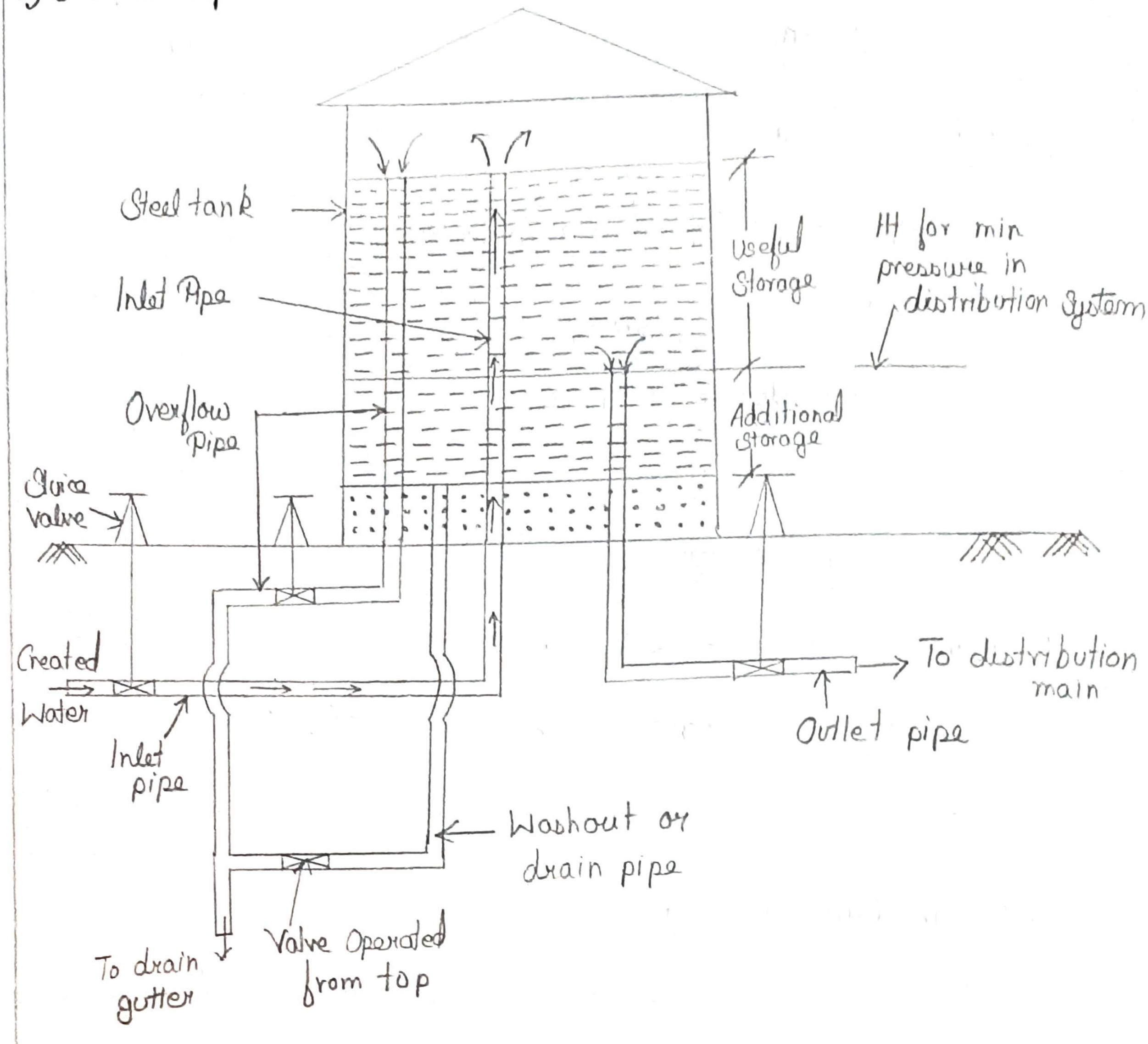
These tanks may be made either of RCC, steel.

Generally the elevated reservoirs are very costly in nature located in the important place of the town or city.

They are generally covered at top by the roof slab in order to avoid the contamination of water.

Roofs should be provided with ventilators, for allowing free circulation of air.

3) Stand Pipes:



They are tall cylindrical elevated shells resting directly on the ground used to store and distribute the water.

The height of the stand pipes varies from 15m to 30m and the diameter varies about 10m to 15 m.

They are made up of RCC or steel.

Like elevated reservoir, stand pipes are also provided with inlet pipe, outlet pipe, drain or wash out pipes, & other miscellaneous facilities such as manholes, ladders, etc.,

Storage Capacity of distribution reservoirs:

It is defined as the quantity of water required to store and distribute the water without any short fall.

Storage capacity of the reservoir includes the

1) Balancing Storage
2) Breakdown storage
3) Fire storage

1) Balancing Storage:

The quantity of water required to be stored in the reservoir for equalizing or balancing the variable demand against the constant water supply is called Balancing or Equalizing Storage.

2) Break down Storage:

The quantity of water preserved in order to tide over the emergencies posed by the pump failures, electricity problems, etc.

3) Fire Storage:

The quantity of water required for firefighting purposes & emergency time is called fire storage or emergency storage.

Network Design:

Pipe Networks is defined as the group of interconnected pipes, forming several loops or circuits.

Following are the conditions of pipe network

1) At a junction, the quantity of inflow of water is equal to the quantity of outflow of water.

2) The loss of head due to flow in clockwise direction is equal to the loss of head due to flow in anticlockwise direction.

3) In each pipe of network there is a relation between the head loss in the pipe and the quantity of water flowing through it.

The loss of head h_f through any pipe discharging at the rate of Q can be expressed as,

$$\boxed{h_f = r Q^n}$$

Where, r - Proportionality Factor

n - Exponent

1) Based on the Hazen - William's Formula

$$\boxed{h_f = \frac{10.68 L (Q^{1.852})}{C_H^{1.852} \cdot D^{4.87}}}$$

By comparing, $r = \dfrac{10.68 L}{C_H^{1.852} \cdot D^{4.87}}$

and $n = 1.852$

2) Based on the Darcy-Weisbach Formula

$$\boxed{h_f = \frac{f L Q^2}{2g \left(\frac{\pi}{4}\right)^2 \cdot D^5} = \frac{f L Q^2}{12.10 D^5}}$$

By comparing $r = \frac{fL}{12.10 D^5}$ and $n = 2$.

Methods of Analysis of Network Design:

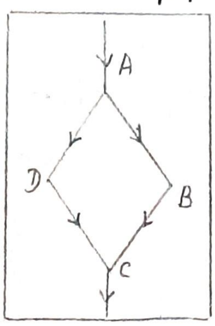
The term analysis of network design means that the analysis of pressure inside the main pipes, sub mains, etc.

The following methods are used to analyse the pressure in the distribution network

1) Equivalent pipe method
2) Hardy cross method
3) Method of sections
4) Circle method
5) Graphical method
6) Electric network analyser method
7) Pitometer distribution studies method.

1) Equivalent Pipe Method:

It is defined as one of the method of analysing the pressure inside the pipes in a distribution system in which the given pipes are replaced by an equivalent pipe.



The equivalent pipe is a single pipe will replace all complex system of pipes with equal head loss for the given flow of water.

This method is based on the concept of replacing the large network of pipes by a single equivalent pipe, having the same discharging capacities and causing the same head loss.

This method is also called Head Balanced Method.

a) Pipe in series:

According to Hazen-Williams Formula the loss of head due to friction in a pipe of length L, diameter D and the roughness coefficient C_H when carrying discharge 'Q' is given as

$$h_f = \frac{10.68\, L\, Q^{1.852}}{C_H^{1.852}\, D^{4.87}}$$

The total head loss due to friction can be obtained by adding the head losses by all pipes

$$h_f = h_{f_1} + h_{f_2} + \ldots\ldots$$

If the pipes are replaced by equivalent pipe of length L_E & diameter D_E, roughness coefficient C_H & carrying the same discharge Q, then,

$$h_{f(Eq)} = \frac{10.68\, L_E\, Q_1^{1.852}}{C_H^{1.852}\, D_E^{4.87}}$$

(12)

$$\therefore \frac{10.68\, L_E\, Q_1^{1.852}}{C_H^{1.852} D_E^{4.87}} = \frac{10.68\, L_1\, Q_1^{1.852}}{C_{H_1}^{1.852} D_1^{4.87}} + \frac{10.68\, L_2\, Q_1^{1.852}}{C_{H_2}^{1.852} D_2^{4.87}} + \cdots$$

(or) $$\frac{L_E}{C_H^{1.852} D_E^{4.87}} = \left[\frac{L_1}{C_{H_1}^{1.852} D_1^{4.87}} + \frac{L_2}{C_{H_2}^{1.852} D_2^{4.87}} + \cdots\right]$$

If $C_H = C_{H_1} = C_{H_2} = \cdots$ then

$$\frac{L_E}{D_E^{4.87}} = \frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}} + \cdots$$

and $$L_E = D_E^{4.87}\left[\frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}} + \cdots\right]$$

(or) $$L_E = D_E^{4.87}\left[\sum_{i=1}^{i=n} \frac{L_i}{D_i^{4.87}}\right]$$

The above equation gives the equivalent length by Hazen-William Formula.

b) Pipes in Parallel :

When pipes are connected in parallel. ABD and ACD, then

$$h_{f(ABD)} = h_{f(ACD)}$$

(or) $$h_{f(AB)} + h_{f(BD)} = h_{f(AC)} + h_{f(CD)}$$

By using Hazen-Williams formula,

$$\frac{10.68\, L_1\, Q_1^{1.852}}{C_{H_1}^{1.852} D_1^{4.87}} + \frac{10.68\, L_2\, Q_2^{1.852}}{C_{H_2}^{1.852} D_2^{4.87}} = \frac{10.68\, L_3\, Q_3^{1.852}}{C_{H_3}^{1.852} D_3^{4.87}} + \frac{10.68\, L_4\, Q_4^{1.852}}{C_{H_4}^{1.852} D_4^{4.87}}$$

When $C_{H_1} = C_{H_2} = C_{H_3} = C_{H_4}$ then

$$\frac{L_1 Q_1^{1.852}}{D_1^{4.87}} + \frac{L_2 Q_1^{1.852}}{D_2^{4.87}} = \frac{L_3 Q_2^{1.852}}{D_3^{4.87}} + \frac{L_4 Q_2^{1.852}}{D_4^{4.87}}$$

$$Q_1^{1.852}\left[\frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}}\right] = Q_2^{1.852}\left[\frac{L_3}{D_3^{4.87}} + \frac{L_4}{D_4^{4.87}}\right]$$

$$\frac{Q_1^{1.852}}{Q_2^{1.852}} = \left[\frac{L_3}{D_3^{4.87}} + \frac{L_4}{D_4^{4.87}}\right] \Bigg/ \left[\frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}}\right]$$

$$\frac{Q_1}{Q_2} = \left[\left(\frac{L_3}{D_3^{4.87}} + \frac{L_4}{D_4^{4.87}}\right) \Bigg/ \left(\frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}}\right)\right]^{1/1.852}$$

(or) $Q_1 = K Q_2$

Where, $K = \left[\left(\frac{L_3}{D_3^{4.87}} + \frac{L_4}{D_4^{4.87}}\right) \Bigg/ \left(\frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}}\right)\right]^{1/1.852}$

If the pipes ABD and ADC can be replaced by an equivalent pipe of length L_E, diameter D_E, roughness coefficient C_H and carrying the total discharge Q, then the loss of head due to friction in the equivalent pipe is given by,

$$h_f = \frac{10.68\, L_E\, Q^{1.852}}{C_H^{1.852}\, D_E^{4.87}}$$

and $h_f = h_{f(ABD)} = h_{f(ACD)}$

$$\frac{10.68\, L_E\, Q^{1.852}}{C_H^{1.852}\, D_E^{4.87}} = \frac{10.68\, L_1\, Q_1^{1.852}}{C_{H_1}^{1.852}\, D_E^{4.87}} + \frac{10.68\, L_2\, Q_1^{1.852}}{C_{H_1}^{1.852}\, D_E^{4.87}}$$

$$\frac{L_E\, Q^{1.852}}{C_H^{1.852}\, D_E^{4.87}} = \frac{L_1\, Q_1^{1.852}}{C_{H_1}^{1.852}\, D_1^{4.87}} + \frac{L_2\, Q_2^{1.852}}{C_{H_1}^{1.852}\, D_2^{4.87}}$$

If $C_{H_1} = C_{H_2} = C_{H_3}$, then

$$\frac{L_E Q_1^{1.852}}{D_E^{4.87}} = \frac{L_1 Q_1^{1.852}}{D_1^{4.87}} + \frac{L_2 Q_1^{1.852}}{D_2^{4.87}}$$

$$L_E = D_E^{4.87}\left[\frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}}\right]$$

2) Hardy - Cross Method:

Hardy-Cross method is a method of controlled trial & error process.

The analysis of pipes network by Hardy Cross method may be carried out in the following two ways,

i) Balancing heads by correcting assumed flows and

2) Balancing flows by correcting assumed heads.

Balancing heads by Corrected Assumed Flows:

In this method the assumed flows are corrected and the procedure is repeated until the loss of head in the loop in the clockwise direction is equal to that in the anti clockwise direction.

The various steps involved in the computation are as follows

i) Assume suitable values of flow Q in each pipe line, such that the flows coming into each junction of the loop are equal to the flows leaving the junction

$$Q_1 + Q_2 + \ldots = Q_6 + Q_7 + \ldots$$

ii) With the assumed values of Q, compute the head loss h_f in each pipe using the equation,

$$h_f = r Q^n$$

iii) Consider different loops and compute the net head loss around each loop considering the head loss in clockwise flows as positive & anticlockwise flows as negative

For any pipe if Q_0 is the assumed discharge and Q is the correct discharge then

$$Q = Q_0 + \Delta Q$$

and the head loss in the pipe

$$h_f = r Q^n = r (Q_0 + \Delta Q)^n$$

Thus for the complete loop

$$\Sigma h_f = \Sigma r Q^n = \Sigma r (Q_0 + \Delta Q)^n$$

By expanding the term in the brackets by binomial theorem

$$\Sigma r Q^n = \Sigma r [Q_0^n + n Q_0^{n-1} \Delta Q + \cdots]$$

If ΔQ is small compared with Q_0 all terms of the series after the second one may be dropped. Thus,

$$\Sigma r Q^n = \Sigma r Q_0^n + \Sigma r n Q_0^{n-1} \Delta Q$$

For the correct distribution the loop is balanced & hence $\Sigma r Q^n = 0$

$$\therefore \Sigma r Q_0^n + \Delta Q \Sigma r n Q_0^{n-1} = 0.$$

Solving for ΔQ

$$\Delta Q = - \frac{\Sigma r Q_0^n}{\Sigma r n Q_0^{n-1}}$$

Design of network system:

It involves the computation of size of the pipes and location of other appurtenances such as valves and hydrants, etc.

No direct method is available for the design and only the trial and error method is adopted.

The following factors are considered in the design of distribution system

1) Type of flow (Continuous flow or Intermittent flow)
2) Method of distribution (Gravity, Pumping or Combined System)
3) Future demand based on increase in population.
4) Design Period to be the life of pipes used.
5) The flow-formula used - Hazen Williams formula

$$V = 0.85\ C\ m^{0.63} i^{0.54}$$

Where, V = Velocity of flow in pipe (m)
m = Hydraulic radius of pipe = H_L/L
i = Hydraulic gradient
C = Friction Coefficient.

C value depends on the type & condition of the pipe used. It is generally taken as 100.

Location and Height of the distribution reservoir:

1) The reservoir should be placed at the centre of the city, in order to distribute the water uniformly & cover the maximum area.

7)

2) It should also be placed near the place, where the high demand of water required, and this will reduce the head loss due to friction.

3) It should be placed at the elevated point of the city, to maintain adequate pressure in the distribution system.

4) It may be placed in between pumping station and distribution area at elevated heights and the water to be supplied will always pass through the reservoir.

Appurtenances in the water distribution system.

Pipe appurtenances are the accessories used in the Water supply and water distribution system in order to test and maintain the system.

The commonly used appurtenances are

1) Valves:

They are provided to control the flow of water. Various functions of valves are

① Control flow of water
② Used to isolate & drain pipeline sections
③ Regulate the pressure of water
④ Used to release or permit the air.

Types of valves:

① Sluice valves (or) Shut off valves (or) Gate valves
② Check valves
③ Air valves

(4) Scour Valves

(5) Anchoring

2) Hydrants :

It is defined as an outlet, in the distribution main or su main for tapping the water during emergencies like fires, etc.,

Types :

(1) Post fire hydrant
(2) Flush fire hydrant.

Location :

(1) All road junctions of important roads
(2) At an interval of about 300m in all important roads.

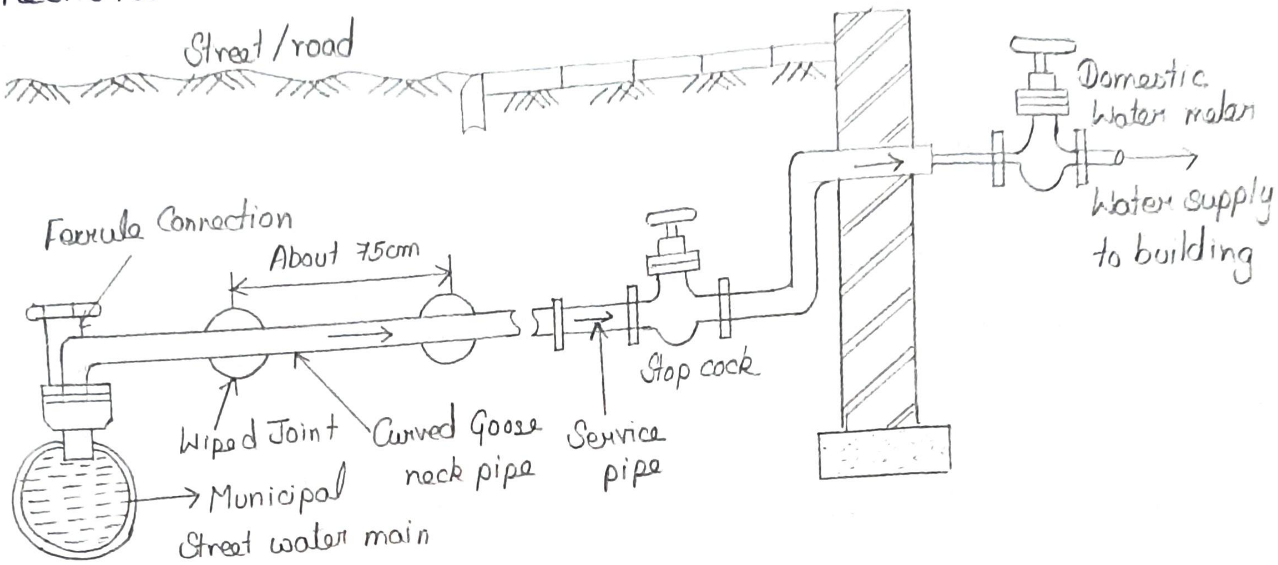
S.No	Post Fire Hydrant	Flush Fire Hydrant
1.	This hydrant is 0.9m to 1.2m above the ground level like a post.	Installed under a brick or CI chamber with its top cover slightly above the road level.
2.	Easily damaged	Not easily damaged
3.	Rarely used	Commonly Used.

House Service Connections and Plumbing System :

House service connections is defined as, the connection taken from the distribution system to the individual residences or buildings.

The Plumbing System consists of supply pipes, distribution pipes, domestic storage tanks, entire system of pipings, fittings, fixtures, appliances, etc.

The following are the components of domestic service connections



1) Ferrule: It is a right angled sleeve made of brass, bronze or gun metal and is joined to a hole drilled in the water main, to which it is screwed down with a plug. Its size usually varies between 10 to 50mm dia.

2) Goose neck: It is a small sized curved pipe made of a flexible material and is about 75 cm in length forming a flexible connection between the water main & the service pipe.

3) Service pipe: It is a galvanised iron pipe of size less than 50mm dia. It should be laid underground in a trench in which no sewer or drainage pipe is laid.

4) Stop cock: The stop cock is provided before the water enters the

water meter in the house.

5) Water meter : It measures and records the quantity of water consumed in the house.

Size of the service pipe:

The following factors governs the size of the service pipe are

1) The minimum pressure in the distribution main
2) Length of the service pipe
3) Number of plumbing fitting
4) Type of plumbing fitting
5) Maximum rate of flow required

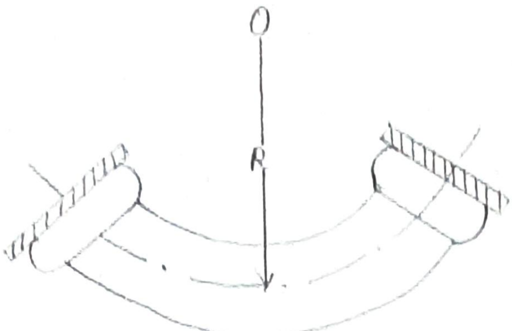
Number of Occupants	4	8	24	60
Dia. of service pipe (mm)	12.5	20	25	30

Pipe fittings:

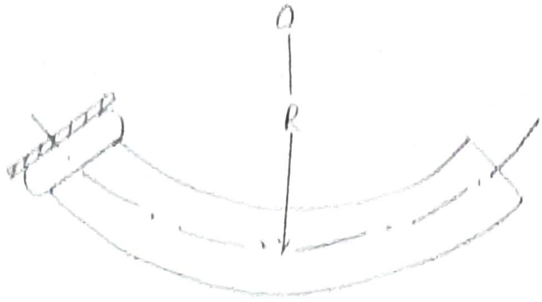
The fittings used to control and to regulate the flow of water in the distribution system is called pipe fittings.

The various pipe fittings are

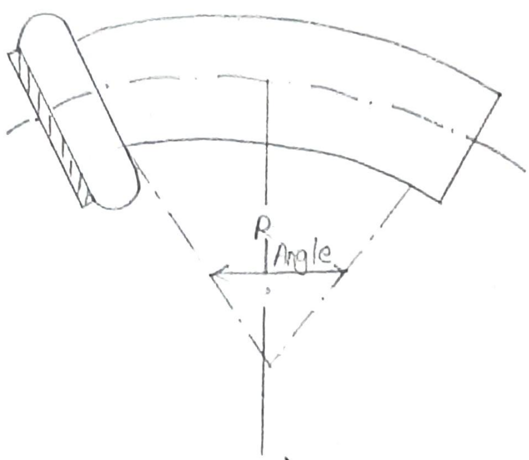
1) Bends
2) Crosses
3) Tees (T-s)
4) Elbows
5) Wyes or Wye connections
6) Caps
7) Flanges
8) Nipples



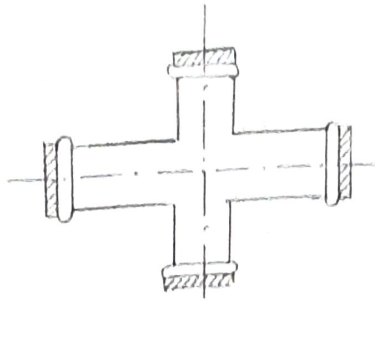
a) 1/4 Bend with double hub



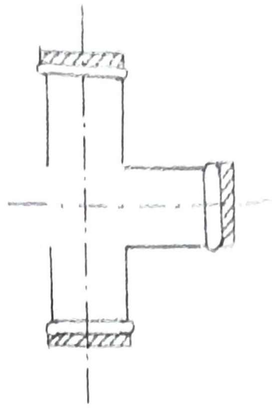
b) 1/4 bend with single hub



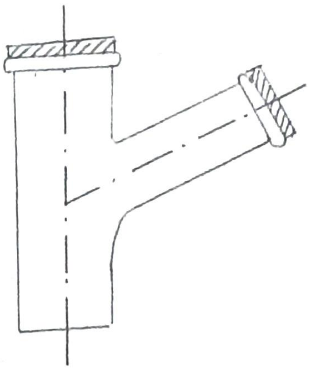
c) 1/8 bend (45")
1/16 bend (22")
1/32 bend (11.25")



d) Cross

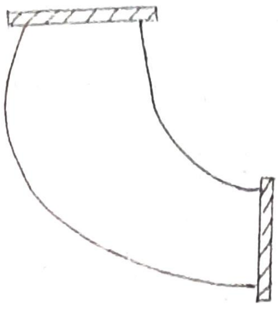


e) Tee

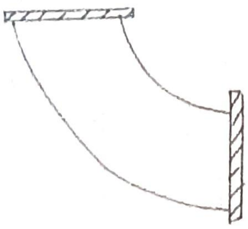


f) Wye

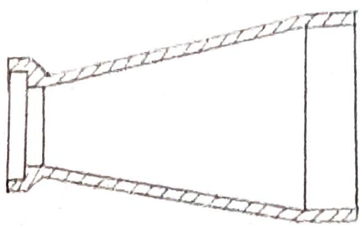
g) Saddle flange



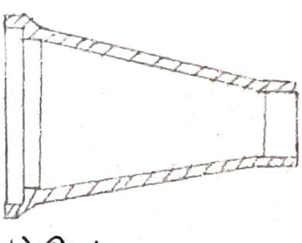
h) Reducing Elbow or bend



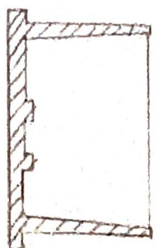
i) Elbow or bend



j) Increaser



k) Reducer



l) Ordinary plug.

Storage of water in buildings:

The system of water supply to a community may be con
or an intermittent one.

In intermittent system it is necessary to store the water in building storage tanks.

Types of storage

1) Over head storage
2) Under ground storage
3) At ground level storage

1) Overhead Storage:

Storage of water are done in small tanks either in concrete, masonry or HDPE (High density Poly ethylene) material, above the roof level of the building.

The storage capacity depends on

1) Rate of water supply
2) Hours or duration of water supply
3) Demand & requirements of buildings
4) Fire Storage.

2) Underground storage:

The RCC, concrete or masonry tanks constructed below the ground level, when the water pressure from the municipal water supply is not sufficient to reach the overhead tanks.

3) At ground level storages:

These are the storage units, located at ground surface or just above the ground surface.

Leak detection:

Leaks are undesirable as in addition to the large amount of wastage, they may cause damages to pavements & other structure close by the water mains.

Methods used for locating leaks are

a) Direct Observation:

In this method, pressure on green grasses during drought, a soft spot in the ground or a metal patch of snow may serve as some indication of the leaks.

b) Sounding rod:

In this method a sharp pointed metal rod is thrust into the ground along the pipe line & pulled up for inspection.

Its moist or muddy point indicates the presence of leakage.

The sound of the escaping water can be heard by placing the ear near the top of the inserted rod.

c) Hydraulic Gradient Line:

In this method the pressures at various points along a

suspended pipe in line are measured & the hydraulic gra(15)
line is plotted.

The appearance of change in the slope of hydraulic gradient line will indicate the location of a leak in the pipe line.

d) Waste detecting meter:

Water Piping Systems in buildings:

They are provided to distribute the water from the water mains to all floors of the buildings.

The various factors considered in the piping system are

1) Pressure of water in the supply mains
2) Quantity of water available & required
3) System of water supply
4) Usage of overhead or underground tanks
5) Cost factors.
6) Availability of power and pumping.

Systems of piping:

1) Piping system using direct water supply
2) Piping system using overhead tanks
3) Piping system using under-ground overhead tanks
4) Pumped system
5) Other piping system

Arrangement of Distribution Pipes & Other Accessories:

The distribution pipe system consists of supply mains, sub mains, branches and laterals, usually made of cast iron and jointed by means of "spigot and socket joints".

The water mains and sub mains are usually laid sloping from high level to the low level areas, so as to achieve the maximum advantages of the available head, & thus to keep their sizes minimum.

Sluice valves are placed along the length of pipe at suitable intervals and also at all junctions & branching off to control the flow of the

Drain valves are placed at all the low points in the distribution pipe system, so as to drain off the water from the pipes for carrying out any repairs, etc.,

Air valves are placed at all the high points so as to remove the air from the pipe during the filling operations, & also to admit air while emptying the pipe.

Layouts of Distribution networks:

The distribution pipes are generally laid below the road pavements, and their layout will generally follow the layouts of the roads.

There are in general, four different types of pipe networks they are as follows

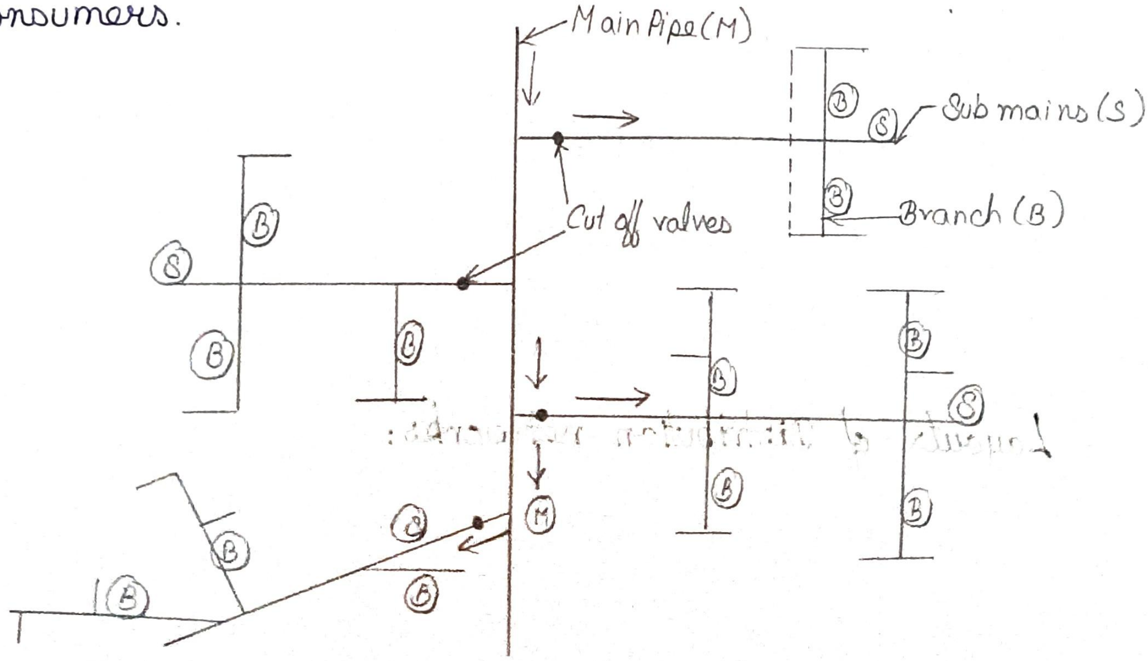
1) Dead end system
2) Grid iron system
3) Ring system
4) Radial System

1) Dead end system:

In the dead end system also sometimes called Tree system there is one main supply pipe, from which originates a number of sub main pipes.

Each submain, then divided into several branch pipes, called laterals.

From the laterals, service connections are given to the consumers.



- This type of layout is adopted for older towns which have developed in a haphazard manner, without properly planned roads.
- The water supply mains have them to be taken along the mains road, & branches taken off whereever needed, thus resulting in the formation of number of dead ends.

Advantages:

1) The distribution network can be solved easily.
2) Lesser number of cut off valves are required in this system.
3) Shorter pipe lengths are needed, and the laying of pipes is easier.
4) It is cheap and simple and can be extended or expanded easily.

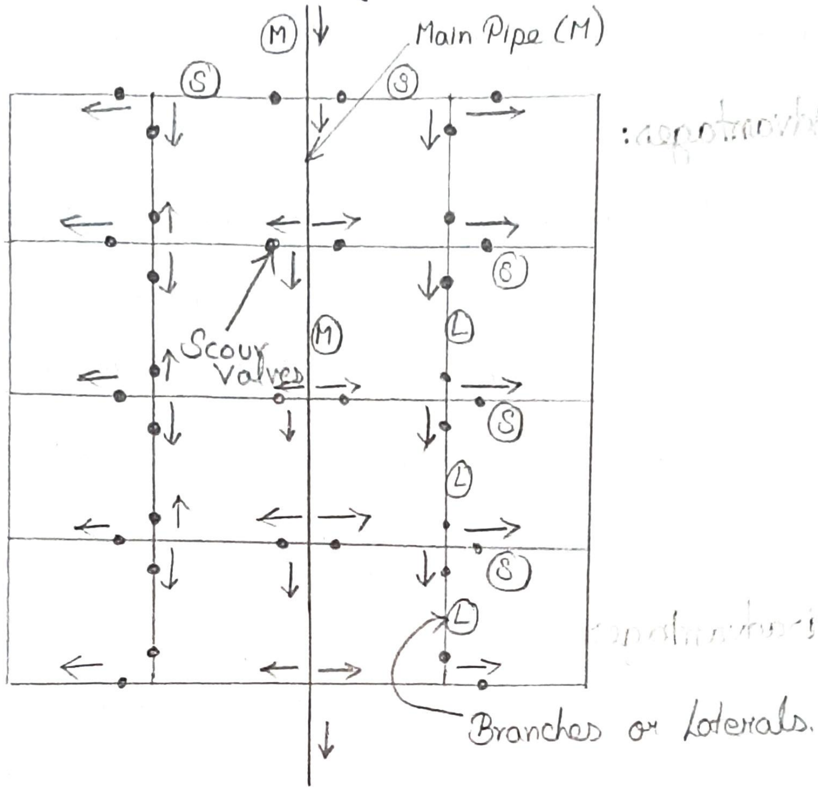
Disadvantages

1) Any damage or repair in any pipe line will completely stop the water supply in the area being fed by that pipe.
2) There are numerous dead ends in the system, which prevents the free circulation of water.
3) The discharge is reaching a point from only one direction, the supplies during fire fighting cannot be increased by diverting any other supplies from any other side.

2) Grid-iron System:

In this system, which is also known as Interlaced system or Reticulation system, the mains, submains and branches are all interconnected with each other.

- In a well planned city or a town, the roads are generally developed in a grid-iron pattern, and the pipe lines in such places can follow them easily.



Advantages:

1) The water reaches at different places through more than one route, the discharge to be carried by each pipe, the friction loss & the size of the pipe therefore gets reduced.

2) In case of repairs, very small area will be devoid of complete supply, as atleast, some supply will be reaching at that point from some other supply.

3) Water remains in continuous circulation, and hence not liable to pollution due to stagnation.

4) Water can be diverted towards the affected point from various directions by closing and manipulating the various cut-off valves.

Disadvantages

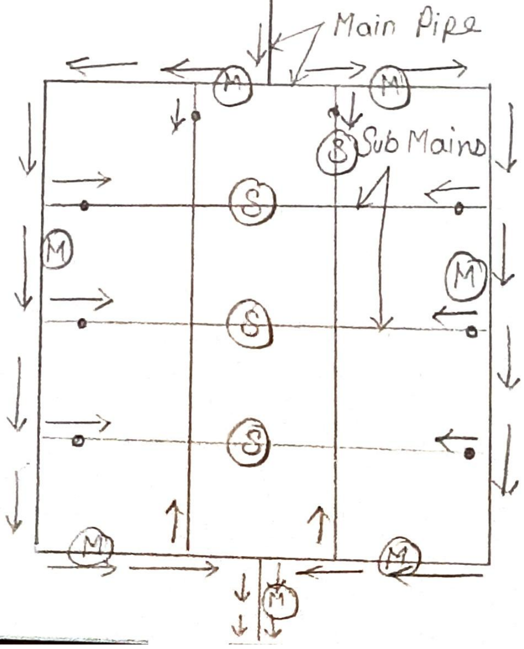
1) It requires more length of pipe lines, and a larger number of sluice valves.

2) Its construction is costlier

3) The design is difficult.

3) Ring System :

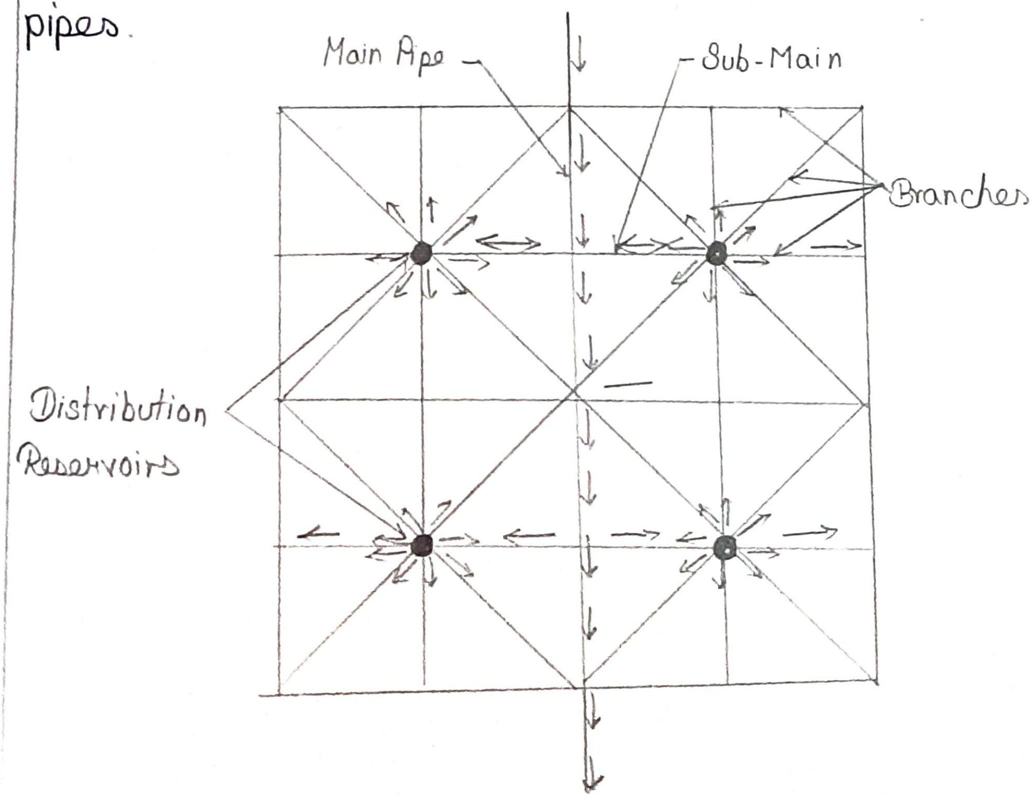
- This system is also sometimes called Circular System.
- In this system, a closed ring, either circular or rectangular of the main pipes, is formed around the area to be served.
- The distribution area is divided into rectangular or circular blocks, & the main water pipes are laid on the periphery of these blocks.



- The ring system is very suitable for towns & cities having well planned roads.
- Advantages and disadvantages are as same as that of the grid iron system.

4) Radial System:

- If a city or a town is having a system of radial roads emerging from different centres, the pipe lines can be best laid in a radial method by placing the distribution reservoirs at these centres.
- Water is taken from the water mains, and pumped into the distribution reservoirs placed at different centres.
- The water is then supplied through radially laid distribution pipes.



- This method ensures high pressures and efficient water distribution
- The calculations for design of sizes are also simple

Methods of Distribution:

The main objective of a distribution system is to develop adequate water pressure at various points of the consumer's taps.

Depending upon the level of the source of water and that of the city, topography of the area, and other local conditions and considerations, the water may be forced into the distribution system in the following three ways.

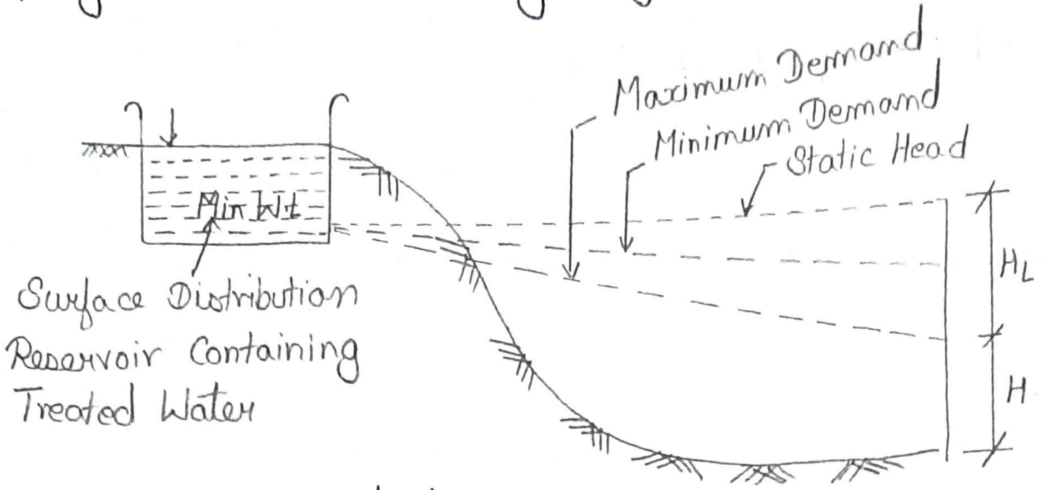
1) by gravitational system
2) by pumping system; and
3) by combined gravity & pumping system

1) Gravitational System:

In this system, the water from the high levelled source is distributed to the consumers at lower levels, by the mere action of gravity without pumping. 2

For proper functioning of this system, the difference of head available between the source and the localities, must be sufficient enough, so as to maintain adequate pressure at the consumer door steps, after allowing the frictional & other losses in the pipes. 3.

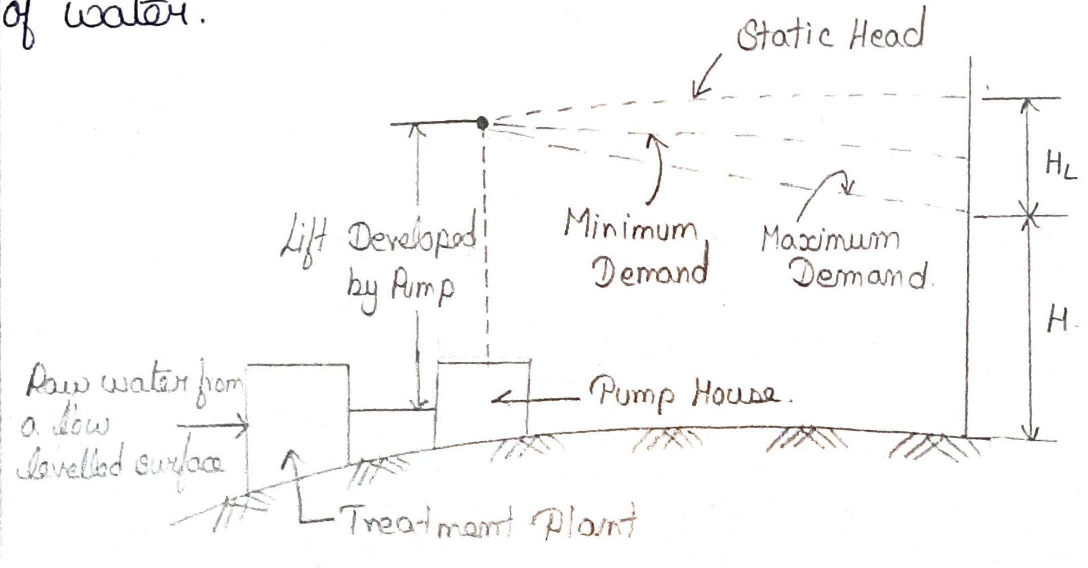
- This method is the most economical and reliable, since no pumping is involved at any stage.



Where H_L = Head Loss
H = Head available to consumers.

ii) Pumping System:

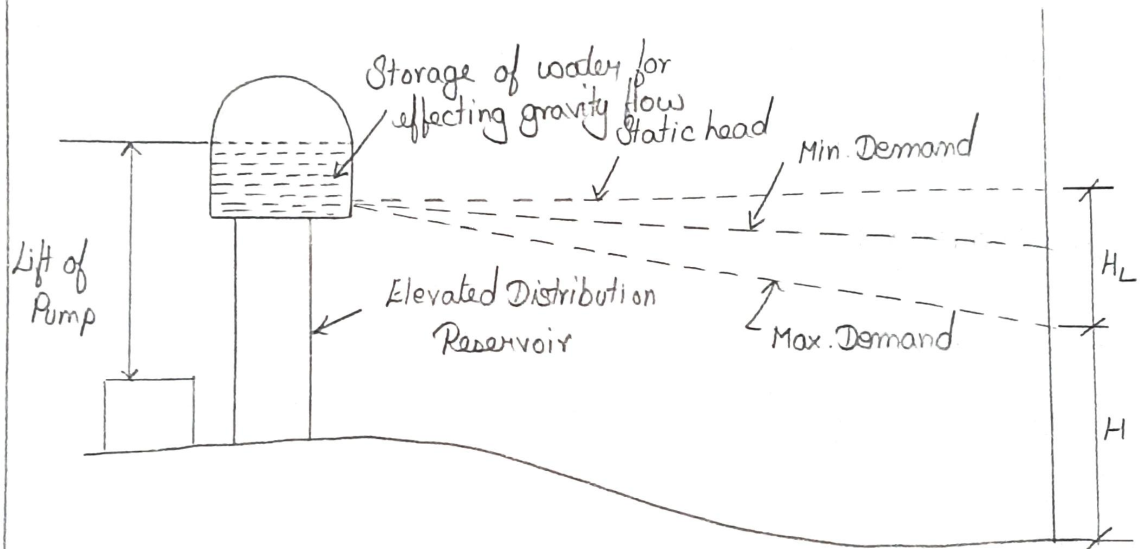
- In this system, the treated water is directly pumped into the distribution mains without storing it anywhere.
- This system is also called pumping without storage system
- High lift pumps are required in this system, which have to operate at variable speeds, so as to meet variable demand of water.



- A continuous attention is needed at this pumping station.
- If the power fails there will be a complete stoppage of water supply.

3) Combined Gravity and Pumping System:

The treated water is pumped at a constant rate and stored into an elevated distribution reservoir, from where it is distributed to the consumers by the mere action of gravity.



Systems of Supply:

The water may be supplied either continuously for all the 24 hours of the day or may be supplied intermittently only for the peak periods during morning & evening.

The intermittent supply system may sometimes lead to some saving in water consumption due to losses occurring for lesser time and more vigilant use of water by consumers.

1) Continous System:

The water is supplied for 24 hours of the day without any stopping

It is possible, where there is availability of water source & water with minimum Impurities

Advantages:

1) Availability of water for 24 hours
2) No necessity of storage of water
3) Useful for emergencies such as fires, meeting, festivals, etc.

Disadvantages:

1) Wastage is more
2) Due to stagnation of water, the surrounding land becomes muddy & gets polluted.

2) Intermittent System:

The water is supplied intermittently, only for the peak period during morning and evening.

Advantages:

1) Wastage is less.
2) Suitable for all places
3) Provides facilities for repair and maintenance.

Disadvantages:

(5)

1) Storage of water is needed.
2) More number of pipe fittings is required.

Maintenance of water supply pipelines.

1) Prevention of leakage of water
2) Clearing of water pipelines
3) Cleaning of appurtenances
4) Repair works.