

ENVIRONMENTAL ENGINEERING (PART-1)

Water is extremely useful to man, providing him luxuries and comforts, in addition to fulfilling his basic necessities of life. It has been estimated that two third of human body is constituted of water. Suitable systems should be designed for collecting, transporting, and treating water.

Essential elements of a public water supply scheme:

- (i) **Intake and reservoir:** To collect water.
- (ii) **Water treatment plant:** Screening, sedimentations, filtration, disinfection units etc.
- (iii) **Elevated tanks and stand pipes:** It provide storage to meet peak demands occurring for limited periods.
- (iv) **Valves:** It control the flow of water in the pipe system.
- (v) **Hydrants:** It provide a connection with the water in the main for fighting fires, flushing streets etc.
- (vi) **Distribution system:** Mains, submains, and branch lines which carry the water to the streets.
- (vii) **Servies:** It carry the water to the individual house etc.

WATER DEMAND

In fact the first requirement is to consider the demand, and the second requirement is to find sources to fulfil that demand.

Various Types of Water Demands:

- Domestic water demand – 55 to 60% of total water consumption.
- Industrial water demand – 50 mp
- Institutional and commercial water demand – 20 lpcd
- Demand for public uses – 10 lpcd
- Fire demand; –1 lpcd and
- Water required to compensate losses in wastes and thefts – 55 lpcd
- As per is 1172-1983 as well as National building code, the domestic consumption under normal conditions in an Indian city is expected to be around 135 litre/head/day.

The break up of 135 lpcd, may be shown below.

Use	Consumption in litres per capita per day
Drinking	5
Cooking	5
Bathing	55
Washing of clothes	20
Washing of utensils	10
Washing and cleaning of houses and residences	10
Flushing of latrines, etc.	30
Total	135

- The ordinary per capital consumption for industrial needs of a city is generally taken as 50 litres/capita/day.
- On an average, per capita demand of 20 l/h/d is usually considered to be enough to meet such commercial and institutional water requirements, although this demand may be as high as 50 l/h/d for highly commercialised cities.
- Demand for public uses is generally taken as 10 l/h/day.

FIRE DEMAND :

- Fire hydrants are usually fitted in the water mains at about 100 to 150 metres apart.
- The per capita fire demand is thus generally ignored while computing the total per capita water requirement of a city.
- Kilo litre of water required = $100 \sqrt{P}$ when population exceeding 50,000 where, P = Population in thousand.
- Rate of fire demand is worked out on the basis of certain empirical formula.

Kuichling's Formula $Q = 3182 \sqrt{P}$

where, P = Population in thousand.

Freeman's Formula

Amount of water required in litres/min,

$$Q = 1136 \left[\frac{1}{10} + 10 \right]$$

For a central congested high value city

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

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- Wastes and thefts, etc. – 55 l/h/d.

PER CAPITA DEMAND.

q = Total yearly water requirement of the city in litres/
 $365 \times$ Design population

- For an Indian city, as per recommendation of IS code, per capita demand, $q = 270$ l/h/d.

Factors Affecting Per Capita Demand

- Size of the city
- Climate conditions
- Types of gentry and habits of people
- Industrial and commercial activities
- Quality of water supplies
- Pressure in the distribution system
- Development of sewerage facilities
- System of supply
- Cost of water
- Policy of metering and Method of charging.

Variation in the Demand

1. Maximum daily consumptions

$$\begin{aligned} &= 180\% \text{ of the annual average daily demand} \\ &= 1.8 \times \text{Average daily demand} \\ &= 1.8q \end{aligned}$$

2. Maximum hourly consumption

$$= 150 \% \text{ of the average hourly demand of the month day.}$$

$$= \frac{150}{100} \times \frac{\text{Maximum daily demand}}{24}$$

$$= \frac{150}{100} \times \frac{108q}{24} = \frac{1.8 \times 1.5}{24} q$$

$$= 2.7 \left(\frac{q}{24} \right)$$

$$= 2.7 \times \text{Annual average hourly demand}$$

- Maximum hourly demand of maximum day = 2.7 q

- Goodrich's formula** $P = 180 + t^{-0.10}$

where, $P = \%$ of the annual average draft for the time t in days.

$$t = \text{time in days from } \frac{1}{24} \text{ to } 365$$

When, $t = 1$ day (for daily variations), then

$$\begin{aligned} P &= 180 \times (1)^{-0.10} \\ &= 180 \end{aligned}$$

$$\therefore \frac{\text{Maximum daily demand}}{\text{Average daily demand}} = 180\%$$

When, $t = 7$ days (for weekly variations), then

$$\begin{aligned} P &= 180 \times (7)^{-0.10} \\ &= 148\% \end{aligned}$$

$$\therefore \frac{\text{Maximum weekly demand}}{\text{Average weekly demand}} = 148\%$$

Similarly, $\frac{\text{Maximum monthly demand}}{\text{Average monthly demand}} = 128\%$

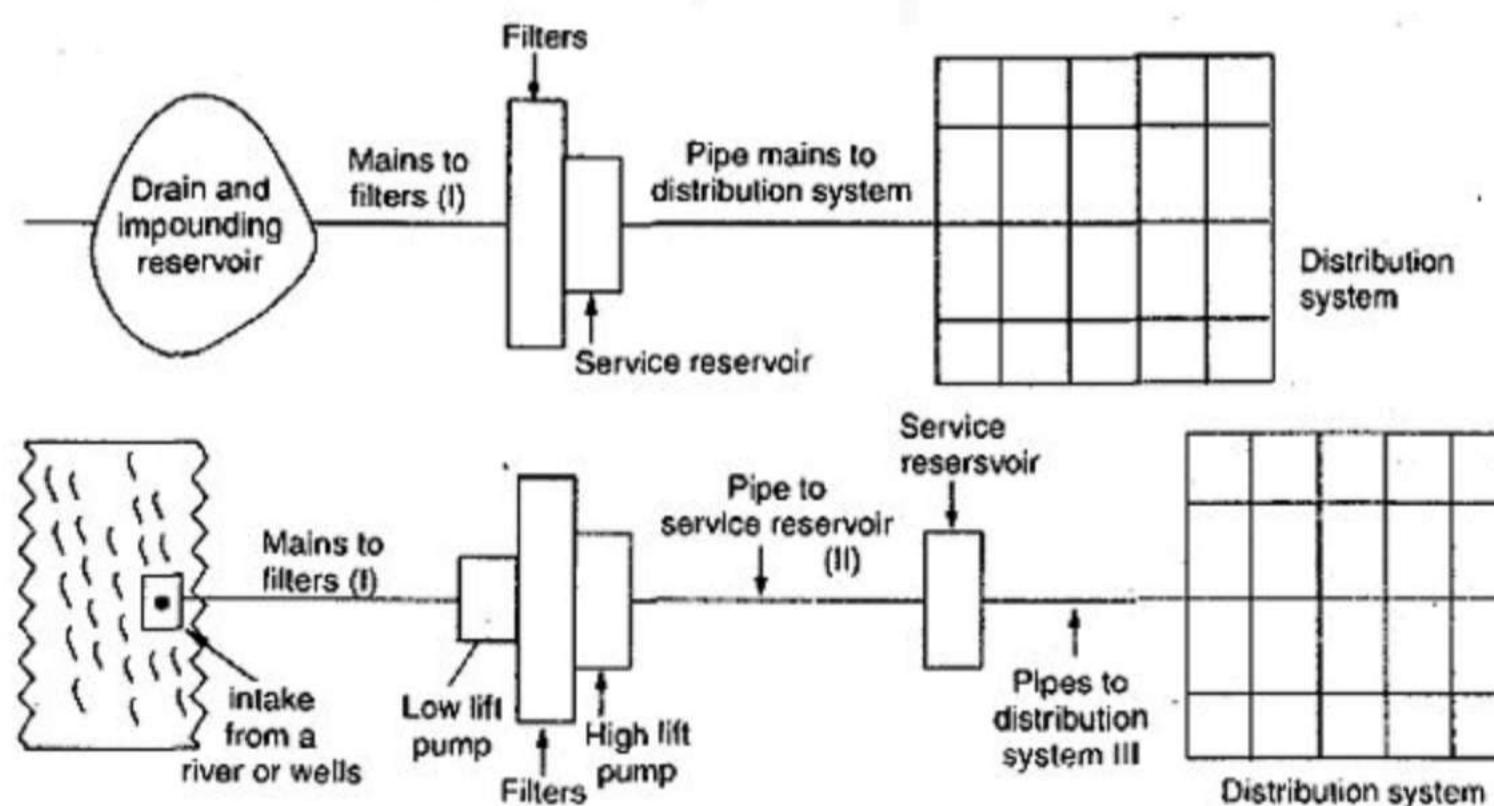
- The pipe mains carrying water from the source to the reservoir is designed for the maximum daily demand.

- Distribution system is designed for maximum hourly demand 5.5.

- The filters and other units of the treatment plant are designed for a 2 times the average daily demand.

- Coincident demand** : The maximum daily demand when added to fire demands for working out total demand is known as *coincident demand*.

WATER SUPPLY SCHEME



- In case of dams and reservoirs - Generally no needs of pumps.
- In case a river is used as a source, is required pumping equipment is required

DESIGN PERIODS & POPULATION FORECASTS

- The future period or the number of years for which a provision is made in designing the capacities of the various components of the water supply scheme is known as **design period**.
- Water supply projects, under normal circumstances, may be designed for a design period of 30 years. This 30 years is to be counted after the completion of the project.

Factor affecting population growth:

- Birth,
- Deaths, and
- Migrations, besides these some other factors like wars, nature havoc and disasters may also bring about sharp reduction in the populations.

Population Forecasting methods:

- Arithmetical increase method,
- Geometrical increase method,
- Incremental increase method,
- Decreasing rate method,
- Simple graphical method,
- Comparative graphical method,
- Master plan method,
- The apportionment method or Ratio method
- The logistic curve method.

Methods 1 to 5 are based on the assumption that factors and conditions which were responsible for population increase in the past and continue even in the future also, with the intensity.

This is a vague assumption.

Methods 6 to 9 are advanced and time consuming methods which gives fair results.

- None of these methods is exact, and they are all based on the laws of probability, and thus, only approximate estimation for possible future population can be made.

1. Arithmetical increase method:

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

where, P_n = Forecasted population after n decades from the present.

P_0 = Population at present (i.e. last known census)

n = Number of decades between present and future.

\bar{x} = Average population increase in the known decades.

2. Geometrical increase method or Uniform increase method:

In arithmetic method, no compounding is done but, in geometric method compounding is done every decade.

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

where, P_0 = Initial population

P_n = Future population after n decades

r = Assumed growth rate (%)

Computation of assumed growth rate (r) from the past known population data.

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

where, P_1 = Initial known population

P_2 = Final known population

t = Number of decades between P_1 and P_2

Note: Arithmetic mean, $r = \frac{r_1 + r_2 + r_3 + \dots + r_t}{t}$

Geometric mean, $r = \sqrt[t]{r_1 + r_2 + r_3 + \dots + r_t}$

where, $r_1, r_2, r_3, \dots, r_t$ are % growth rates of the several known decades of past.

Arithmetic mean is slightly higher than geometric mean

Also r can be calculated as

$$r = \frac{\text{increase in population}}{\text{original population}} \times 100$$

Note: In geometric method computing is done every decade

3. Incremental increase method or Method of varying increment:

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

where, P_n = Population after n decades from present

P_0 = Present population

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

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

- Population obtained by

Arithmetic increase method < Incremental increase method < Geometrical increment method.

- Incremental method gives quite satisfactory results.
- For new younger cities expanding at faster rates → Geometrical increment method is applied.
- For old cities → Arithmetic method is better.
- Incremental method is applied for any type of city.

4. Decreasing rate method:

- This method is applicable only in cases where the rate of growth shows a downward manner.
- In this method, the average decreases in the percentage increases is worked out, and is then subtracted from the latest percentage increase for each successive decade.

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Example:

Year	Population	Increase in population	% increase in population	Decrease in % increase
1990	80,000	40,000	50%	10%
1950	1,20,000	98,000	40%	4%
1960	1,60,000	98,000	36%	
1970	2,28,500	60,500		
			Total	14%

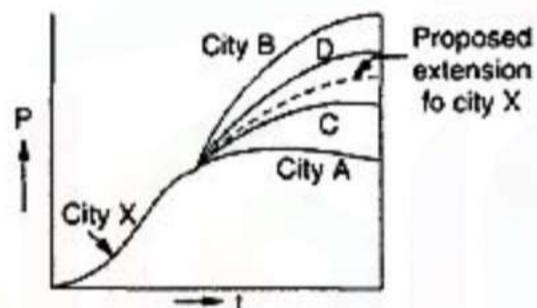
$$\text{Average per decade} = \frac{14}{2} = 7\%$$

$$\begin{aligned}\therefore P_{1980} &= 2,28,580 + \left(\frac{36-7}{100} \right) \times 2,28,580 \\ &= 2,28,580 + \frac{29}{100} \times 2,28,580 = 2,94,870 \\ P_{1990} &= 294870 + \left(\frac{29-7}{100} \right) \times 294870 \\ &= 294870 + \frac{22}{100} \times 294870 = 3,59,740\end{aligned}$$

5. Simple graphical method:

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

6. Comparative graphical method:



7. Master plan method:

It is very easy to access precisely the design population, because the master plan will give us as to when and where the given number of houses, industries and commercial establishment would be developed.

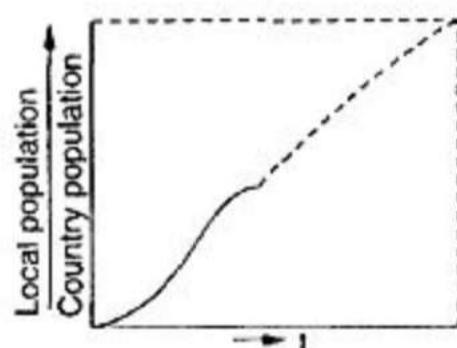
8. Apportionment method or Ratio Method :

The local population and the country population for the last four or five decades is obtained from the census method.

9. The logistic curve method:

Equation of the logistic curve

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



where, P = Population at any time t from the origin A

P_s = Saturated population

$$m = \frac{P_s P_0}{P_0^2}$$

(a constant)

$$n = kp_s$$

(another constant)

P_0 = Population at the start point of the curve.

k = constant

- If only three pairs of characteristic values P_0, P_1, P_2 at time $t = t_0 = 0, t_1$ and $t_2 = 2t_1$ extending over the useful range of the census population are chosen, then

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

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

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

SOURCES OF WATER

After calculating the demand of water, the main job is to search the source of water.

Various sources of water available on the earth can be classified into the following two categories:

A. Surface sources:

- Ponds and lakes;
- Streams and rivers;
- Storage reservoirs; impounding reservoir, and
- Ocean, generally not used for water supplies; at present.

B. Sub-surface sources or Underground sources:

- Spring
- Infiltration galleries
- Infiltration wells
- Wells and tube-wells.

- The yield which correspond to the worst or most critical year on record is called **firm yield** or **safe yield**.

Hydrologic Principles

- The precipitation and evaporation continues forever, and thereby a balance is maintained between the two. This process is known as **hydrological cycle**.
- The evaporated water comes back to the surface of the earth in its various forms like rain, snow, hail, mist, sleet etc. is known as **precipitation**.
- A major part of the precipitation occurs in the form of rain, and a minor part occurs in the form of snow.

PRECIPITATIONS

Types of Precipitations :

- Cyclonic precipitation;
 - Convective precipitation; and
 - Orographic precipitation.
- The usual mechanism by which the air is cooled to cause precipitation is the lifting of the air mass.
 - Cyclonic precipitation:** It is caused by the lifting of the air mass due to the pressure difference. If low pressure occurs in an area, air will flow horizontal from the surrounding area, causing the air in the low pressure area to lift. The precipitation that results, is called *non-frontal cyclonic precipitation*. If one air mass lifts over another air mass, then the precipitation is called **frontal or cyclonic precipitation**.
 - The boundary between these two air masses of different temperatures and densities is known as a **front** or a **frontal surface**.
 - The large whirling mass of air, at the centre of which the barometric pressure is low, is known as a **cyclone**.
 - Convective precipitation:** Convective precipitation is due to the upward movement of air that is warmer than its surroundings. Precipitation occurs of high intensity and short duration.
 - Orographic precipitation:** Orographic precipitation is the most important precipitate which is responsible for most of the heavy rains in India. Orographic precipitation caused by air masses which strike some natural topographic barriers like mountain and cannot move forward, and hence rise up, causing condensation and precipitation.

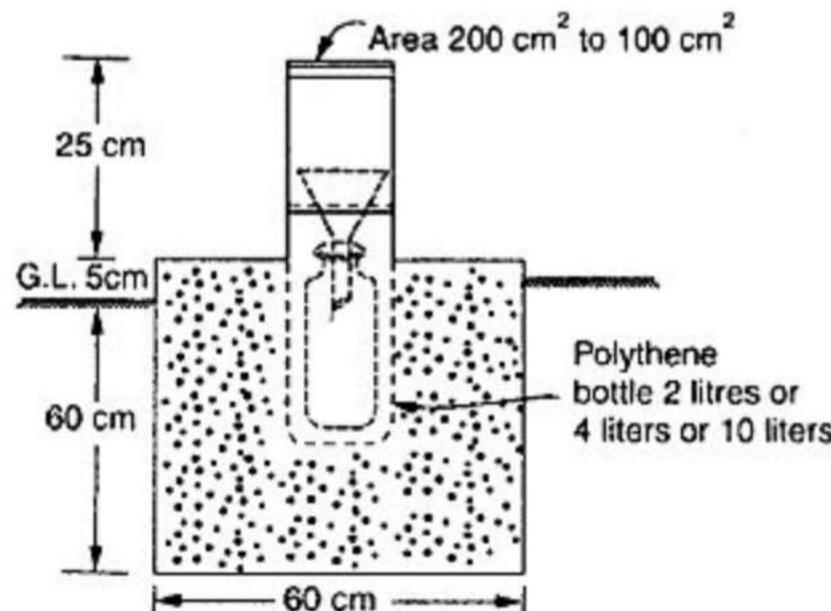


Fig. Standard non-recording raingauge.

RAINFALL AND IT'S DISTRIBUTION

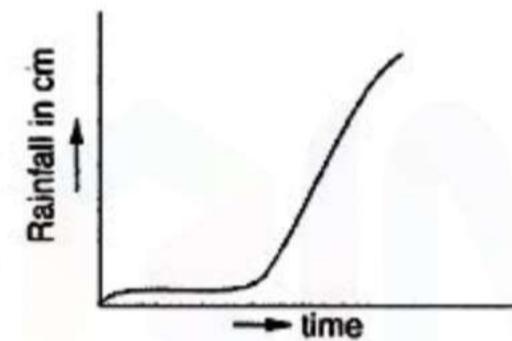
- Rainfall interception (P_i)**: The rain interrupted by buildings and trees.
- Ground rainfall (P_g)**: Total rainfall = $P - P_i$
- Infiltration (F)** : The ground rainfall infiltrated by the soil.
- The maximum rate at which the soil in a given condition can absorb water is known as **infiltration capacity (f)**.
- Depression storage (S_d)** : None of it appear as surface runoff.
- Rainfall excess (P_e)**: $(P_e) = \text{Rainfall rate} (P) - \text{Infiltration capacity} (f)$

Measurement of Rainfall :

Two types of raingauge :

- Non-recording type** → Symen's type (Obsolete)
(only collect the rain) → Standard gauges adopted by Indian Metrological department (MID.).

- Recording type rain gauge:** It gets recorded automatically on a graph paper. This gauge thus produces a record of cumulative rain Vs. time in the form of graph, which is known as the **mass curve of rainfall**.



- It is also known as integrating raingauges or continuous rain-gauges.
- Various type of Recording Raingauges :
 - Tipping bucket type-operated through telecommunication system.
 - Weighing type
 - Floating type, etc, (most widely used in India).

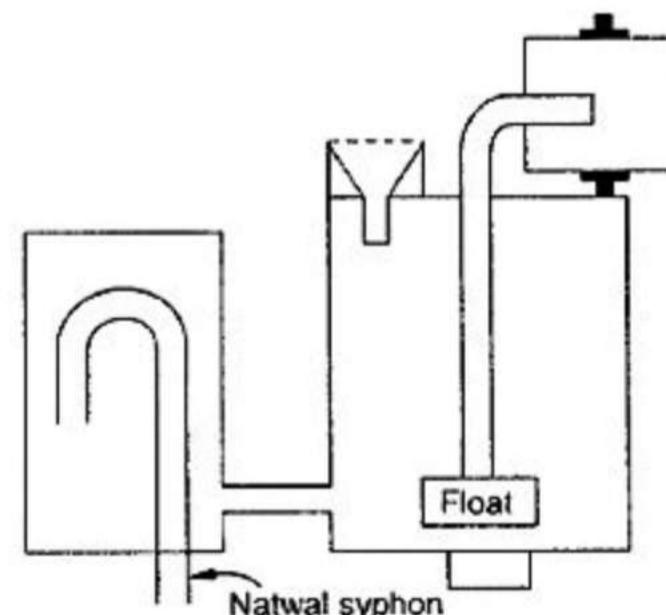


Fig. Float type automatic raingauge.

8.6 Environmental Engineering

- The rotating drum completes one revolution in 24 hours or sometimes in 7 days.

Average annual rainfall

$$\text{Annual rainfall at a given station should be recorded over a number of years (35 years)}$$
$$= \frac{\text{Number of years}}{\text{Number of years}}$$

Index of Wetness.

Index of wetness

$$= \frac{\text{Actual rainfall in a given year at a given place}}{\text{Normal rainfall of that place (i.e. Average)}}$$

- Index of wetness, gives us an idea of the wetness of the year.
- 60% index of wetness means a rain deficiency of 40%.
- A deficiency of about 30 to 45% is known as **large deficiency**.
- A deficiency of about 45 to 60% is known as **serious deficiency**.
- A deficiency more than 60% is known as **disastrous deficiency**.

The year in which the rainfall is less than the average annual, is called a **bad year** or a **sub normal year**; and the year in which the rainfall is more than the average, is called a **good year**. If the rainfall in a particular year is approximately equal to the annual average value, then it is known as a **normal year**.

The average annual rainfall of a given place is very useful for planning water supply schemes at that place, because it direct gives us an idea of the probable amount of water that may be available at that place.

ESTIMATING RUN-OFF AND YIELD OF A BASIN.

1. English Formula:

$$Q_y = 0.85 P_y - 304 \quad \text{for hilly catchment}$$
$$Q_y = P_y \left[\frac{P_y - 17.8}{254} \right] \quad \text{for plane catchment}$$

Used in South India.

where, Q_y = yearly runoff in cm depth over the basin

P_y = yearly precipitation or annual rainfall in cm.

2. Khosla's Formula:

$$Q_y = P_y - 0.4813 T_m \quad (T_m > 4.5^\circ\text{C})$$

3. $Q_y = KP_y$

where, K = Impervious factor.

This runoff is helpful in evaluating the amount of water available in the river over long periods. They are, therefore, useful for estimating the storage capacity of the reservoir, and this fixed the height of the dam required to be constructed for that storage. These determinations are hence useful when storage reservoir is to be used as a source of water. However, when a river or a stream is to be directly used as a source of water, we must determine the day to day quantities of flow in that river or stream.

SURFACE SOURCES OF WATER SUPPLIES

Ponds and Lakes as Surface Sources of Supplies:

- If the size of the depression is comparatively small, it may be termed as a **pond**, and when the size of depression is larger, it may be termed as a **lake**.
- Bleaching of colour.
- Due to the smaller quantity of water available from them, lakes are not considered as principal source of water supplies.

Streams and Rivers as Surface Sources of Supplies:

- Small stream channels feed their waters to the lakes or rivers.
- Rivers are the most important sources of water supply schemes.
 - (a) Perennial river - water is available throughout the year.
 - (b) Non-perennial rivers.

Storage Reservoirs as Surface Sources of Supplies:

A water supply scheme drawing water directly from a river or a stream may fail to satisfy the consumers demands during extremely low flows. To avoid such problem we construct a dam across a river for storage of water. The artificial lake is formed on the up stream side is known as **storage reservoir**.

- The subject of design and planning of dams and reservoirs is a big topic in itself, and is generally dealt under the subject of irrigation.
- Surface waters are, however, generally soft and less corrosive than ground waters. On the whole it can be stated that the surface supplies are generally contaminated and cannot be used without treatment.

SUBSURFACE OR UNDERGROUND WATER SOURCES

- Sometimes, the ground water is brought to the surface by some natural processes like **springs**, and sometimes the water is tapped by artificial means by constructing wells, tubewells, infiltration galleries etc.
- Since the ground water is largely tapped in our country for water supplies and there is a scope for its development in future also.

Factors Governing the selection of a particular source of water:

- Quantity of available water.
 - Quality of available water.
 - Distance of the source of supply.
 - General topography of the intervening area.
 - Elevation of the source of supply.
- The dead storage zone in a reservoir is provided for storage of sand and silt.
 - Trap efficiency

$$= \frac{\text{Total sediment deposited in the reservoir}}{\text{Total sediment flowing in the river}}$$

- With the reduction in the reservoir capacity, the quantum of sediment trapped by it decreases.

DEVELOPMENT OF GROUND WATER

Geological factors governing the occurrence of ground water

The possibility of occurrence of underground water mainly depends upon two properties of the underground soil, i.e.

- Porosity of the soil; and
- Permeability of the soil.

- $\eta = \frac{V_v}{V} \times 100(\%)$
- Uniform and well sorted grains give rise to higher porosity; whereas heterogeneous grains with irregular arrangement reduces the porosity.

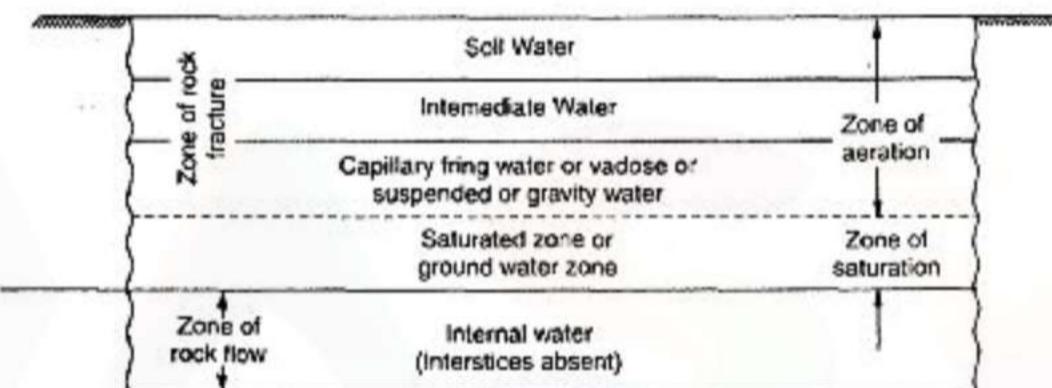
Porosity values of a few Rock Formations:

Granite, Quartzite	-	1.5%
Slate, Shale	-	4 %
Limestone	-	5 to 10 %
Sandstone	-	10 to 15 %
Sand and Gravel	-	20 to 30 %
Only gravel	-	25%
Only sand	-	35%
Clay and Soil	-	45%

Permeability and Transmissibility

- The porosity of the rock, thus, defined the maximum amount of water that can be stored in the rock. This porosity, however, in itself, does not ensure the storage of underground water, because the water can enter into a rock only if the rock permits the flow of water through it.
- A rock which is porous, may or may not be permeable.
- The capability of the entire soil of full width and depth is represented by **Permeability**; while that of the soil of unit width and full depth is known as **Transmissibility**.
- The permeability is measured in terms of coefficient of permeability.

Zones of Underground Water



- In the zone of saturation, water exists within the interstices and is known as *ground water*. This is the most important zone for a ground water hydrologic engineering because it has to tap out this water. Water in this zone is under hydrostatic pressure.

$$Q = kiA$$

$$V = ki$$

where, V is the discharge velocity not the actual velocity (V_a) through the soil medium.

- $A_v V_a = A \times V$
where, A_v = cross-sectional area of void

$$V = \frac{A_v}{A} V_a$$

$$V = \eta V_a$$

$$V_a = \frac{V}{n} = \frac{ki}{n}$$

- 1 Darcy = 9.87×10^{-9}
- Intrinsic permeability or specific permeability
$$k_o = \frac{kv}{g} = k \left(\frac{\mu}{\gamma w} \right)$$
- Relation between coefficient of permeability (k) and coefficient of transmissibility (T).
$$T = kd$$

where, d = mean particle size of porous medium.

- Drainage of ground water means extracting the water from below the water table through well, infiltration galleries, springs, etc.

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Porosity

$$= \text{Specific yield} + \text{Specific retention}$$

$$= \frac{\text{Volume of water obtained by gravity drainage}}{\text{total weight of the material drained}}$$

$$+ \frac{\text{Volume of water held against gravity drainage}}{\text{total weight of the material drained}}$$

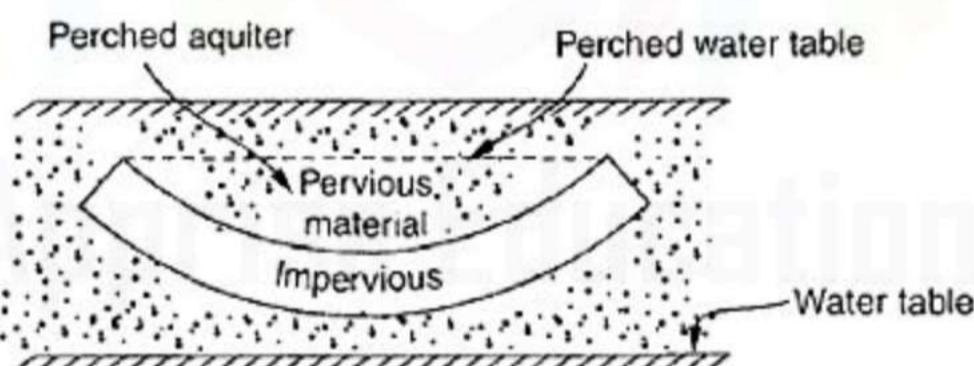
- Large particles of soils like coarse gravels, the specific retention would be small and it would result in large specific yields.
- Water bearing formation of coarse gravel would supply large quantities of water to wells, whereas clay formations, although saturated and of high porosity, would be of little value in this respect.

AQUIFERS

Types of Aquifers:

1. Unconfined or **Non-artesian** aquifers; and
 2. Confined or Artesian aquifer.
- The top most water bearing stratum having no confined impermeable overburden (i.e. aquiclude) lying over it, is known as unconfined aquifer or non-artesian aquifer.
 - When an aquifer is confined on its upper and under surface, by impervious rock formation (i.e. aquiclude), and is also broadly inclined so as to expose the aquifer for somewhere to the catchment area at higher level for the creation of sufficient hydraulic head, it is called a **confined aquifer** or **an artesian aquifer**.

Perched aquifer:



- **Aquifuse**: It is that geological formation which is, neither porous nor permeable. Granite rock is an example of aquifuse.
- **Aquitard**: It is that geological formation, which does not yield water problems to wells due to its lesser permeability. The yield from such a formation is, thus insignificant. e.g., sandy clay.
- **Aquiclude**: It is highly porous, containing large quantities of water, but essentially impervious. e.g. clay layer.

Storage co-efficient (A)

It is defined as the volume of water that an aquifer releases or storage per unit surface area of the aquifer per unit change in the component of head normal to

that surface. The storage coefficient (A) for an artesian aquifer is equal to the volume of the water released from the aquifer of full height and unit area when the piezometric surface declines by unity.

GROUND WATER SPECIFIC YIELD

It is the ratio of volume of water obtained by gravity-drainage to the total volume of the subsoil i.e.

$$\text{Specific yield} = \frac{\text{Volume of water obtained by gravity drainage}}{\text{Total volume of the sub-soil}} \times 100$$

$$\text{Specific retention} = \frac{\text{Volume of water held against gravity drainage}}{\text{Total volume of the material}} \times 100$$

$$\text{Porosity} = \text{Specific yield} + \text{specific retention}$$

GROUND WATER VELOCITY

$$(a) \text{ Slichter's formula: } v = \frac{k' SD^2}{\mu}$$

where, v = velocity of ground water in m/day

k' = constant (approx. 400)

s = slope of hydraulic gradient line

D = effective size of the particle in aquifer (in mm)

μ = dynamic viscosity

$$(b) \text{ Hazen's formula: } v = \frac{k'' SD^2}{60} (1.8T + 42)$$

where, K'' = constant (approx. 1000)

T = Temperature (in °C)

Specific yield of well in recuperating test can be determined from the following formula:

$$\frac{C'}{A} = \frac{2.3}{T} \log_{10} \frac{S_1}{S_2}$$

Where, S_1 = depression head in the well immediately after the pumping was stopped.

S_2 = depression head in well at time 'T' after the pumping was stopped.

T = time after which S_2 was measured

$$\frac{C'}{A} = \text{specific yield.}$$

$$\text{Discharge, } Q = \left(\frac{C'}{A} \right) \cdot AS$$

where, A = cross-sectional area of well

- Yield of a well,

$$\begin{aligned} Q &= \frac{\pi \rho k (H^2 - h^2)}{2.3 \log_{10} R/r} m^3 / \text{day} \\ &= \frac{\pi \rho k \times 1000}{2.3 \times 24 \times 60} \frac{H^2 - h^2}{\log_{10} R/r} \text{ litres/minute} \\ &= \frac{k_m H^2 - h^2}{\log_{10} (R/r)} lpm \end{aligned}$$

where, $k_m = \frac{\pi \rho k \times 1000}{2.3 \times 24 \times 60}$ is known as transmission constant of the aquifer.

- The above formula is known as **Thiem's formula**. Yield of tubewell when equilibrium conditions have not reached can be determined using following formula:

$$s = \frac{Q}{4\pi\mu} \left[\log e \left(\frac{4T\mu}{r^2 A} \right) - 0.5772 \right]$$

where, s = draw down in observation well after time T .

r = radial distance of the observation well from the main well.

Q = yield or constant discharge pumped out from the well.

A = coefficient of storage of measured drawdown.

μ = coefficient of transmissibility.

$$s_1 - s_2 = \frac{2.3Q}{4\pi\mu} \log_{10} \left(\frac{T_2}{T_1} \right)$$

Various forms of underground sources and their exploitation

The underground water is generally available in the following forms :

1. Infiltration galleries
2. Infiltration wells
3. Springs
4. Wells including tubewells.

INTAKE FOR COLLECTING SURFACE WATER

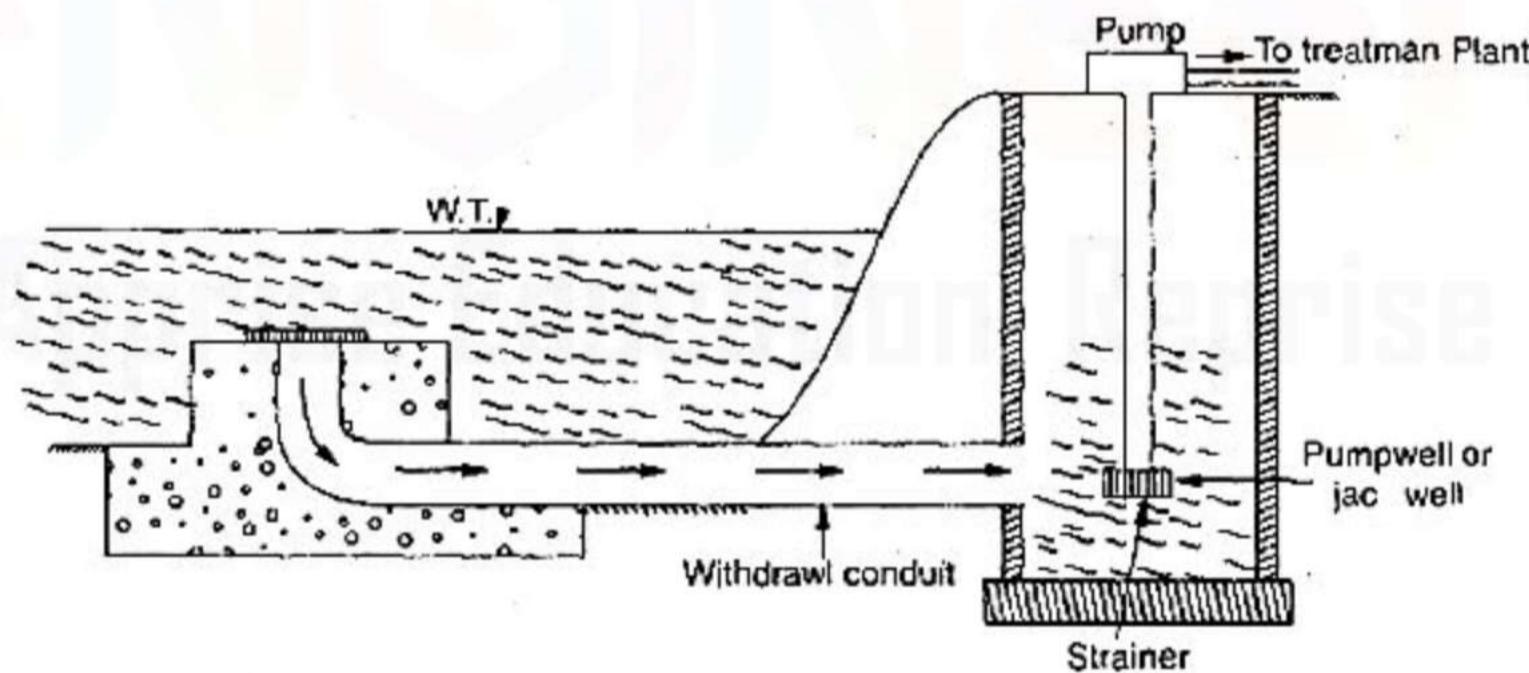
The basic function of the intake structure is to help in safely withdrawing water from the source over a predetermined range of pool levels and then to discharge this water into the withdrawal conduit, through which it flows upto the water treatment plant.

Site Selection of Intake depends on

- Availability of water in all seasons.
- Quality and quantity of water.
- Away from the pollution.
- Nearer to the city.
- Upstream side of the river.
- Costs and reliability.

Types of Intakes:

1. Simple Submerged Intakes:



These intakes are not used on bigger projects on river and reservoir, as their main disadvantage is the fact that they are not easily accessible for cleaning, repairing, etc.

2. Intake Tower :

- | | | |
|----------------------------|---|------------------------------------|
| (i) Wet intake towers; and | } | Standing in the river or reservoir |
| (ii) Dry intake towers | | |
- The essential difference between a dry intake tower and a wet intake tower is that, in a wet intake tower, the water enters from the entry ports into the tower and then it enters into the conduit pipe through separate gate controlled opening; but in a dry intake tower, the water is directly drawn into the withdrawal conduit through the gated entry ports.

3. Medium sized intake wells (River intake) :

(i) **Medium sized river intake:** The water from the intake chamber is taken through a withdrawal conduit (called intake conduit) to a sump well, from where it is lifted and taken to the treatment plant.

(ii) Canal intake well

Design criteria

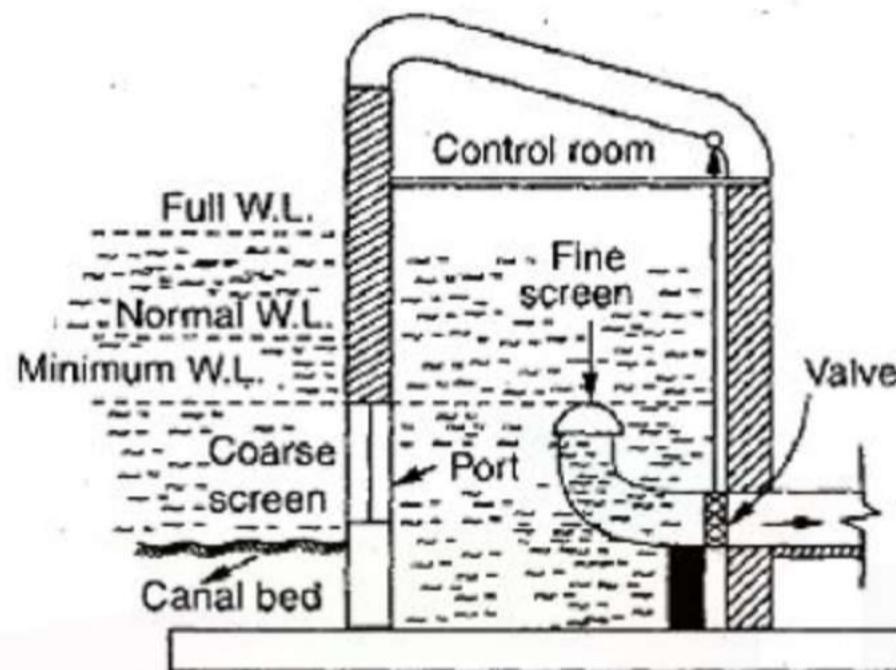


Fig. Canal intake well

- 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 0.45 m above the canal bed to avoid entry of bed load.
- An additional fine screen is provided at the inlet end of the withdrawal conduit. This inlet end of bell mouth shape with perforation of fine screen on its surface.
- An outlet valve, operating from the top, is provided to controlled entry of water into the outlet pipe.
- The flow velocity through the outlet conduit is generally kept as about 1.5 m/sec and this helps in determining the area and diameter of the withdrawal conduit.
- The area of coarse screen is designed by limiting the flow velocity to as low as 0.15 m/sec or so. The flow velocity through the bell mouth inlet is limited to about 0.3 m/sec or so.
- The head loss in the intake conduit upto treatment works, can be determined by using Darcy Weisback formula

$$H_L = \frac{f' LV^2}{2gd}$$

or by using Hazen William's formula.

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

where, $S = \frac{H_L}{L}$ = slope of the energy line

$C_H = 130$ for C.I. pipe.

4. Intake for Sluiceways of dam:

In case a reservoir developed by constructing a dam, it is a common practice to fetch water through the sluiceways from inside the dam.

- In case of earthen dams, the intake for withdrawing water into the sluiceway of the dam, is generally located near the upstream toe of the dam. Whereas for masonry dam the intake well for withdrawing water is generally located inside the body of the dam.
- The arrangement is similar to that of a dry intake tower, only different that it was surrounded by water on all sides and was standing in the river, whereas this valve tower is fed through conduits and is standing in the dam or very near the dam.

Design and Sketch of River Intake:

- Population = 50,000; demanding water @ 135 Ipcd
R.L.D. bed of river – 50.00 m.
R.L of L.W.L. – 52.5 m.
R.L of H.W.L. – 55.5 m.

Assume other data necessary for design.

$$\begin{aligned} Q &= 50000 \times 135 \\ &= 6750000 \text{ l/d} = 0.07 \text{ m}^3/\text{sec} \end{aligned}$$

Taking detention time in the intake well = 20 minute (IS code: 10—30 minutes)

$$\text{Volume of the intake well} = Q \times \text{D.T.} = 0.078 \times 20 \times 60 = 94 \text{ m}^3$$

For minimum assured water, $h = 2.5$ metre.

$$\therefore 94 = \frac{4}{9} D^2 \times h = \frac{4}{9} D^2 \times 2.5 = 94$$

Hence, Diameter of intake well, $D = 7\text{m}$.

Provide 2 well one working and other stand by;

Flow velocity through coarse screen = 0.15 m./sec.

Flow velocity through fine screen = 0.30 m./sec.

Velocity through pipe = 1 m./sec.

Provide height of coarse screen (20 mm diameter bars @ 40 mm/cm.) = 2 m.

$$\text{Net area required} = \frac{Q}{V} = \frac{0.078}{0.15} = 0.52 \text{ m}^2$$

$$\therefore \text{Gross area of screen} = 2 \times 0.52 = 1.04 \text{ m}^2$$

$$\therefore \text{Length of screen} = \frac{1.04}{2} = 0.52$$

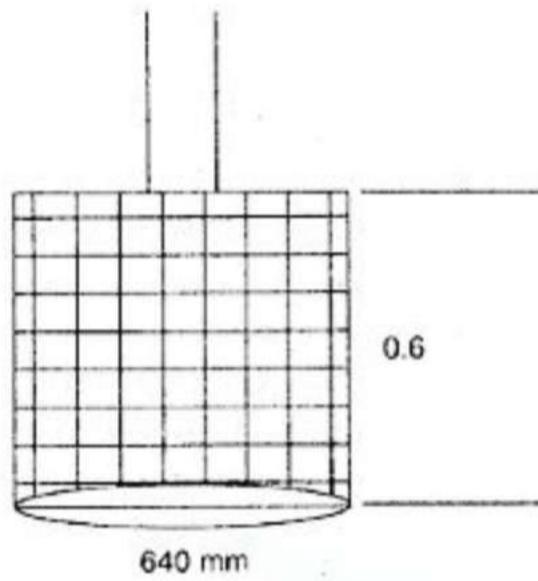
• Pumping design:

Pumping design for $1\frac{1}{2}$ times average flow of pumping is running for 16 hours. Then

$$\text{Design flow, } Q = Q_{av} \times 1.5 \times \frac{24}{16}$$

$$= 0.078 \times 1.5 \times \frac{3}{2}$$

$$= 0.176 \text{ m}^3/\text{sec.}$$



$$\text{Net area for strainer} = \frac{Q}{V} = \frac{0.176}{0.3} = 0.6 \text{ m}^2$$

$$\therefore \text{Gross area} = 2 \times 0.6 = 1.2 \text{ m}^2$$

Provide length of strainer = 0.6 m.

$$\therefore \text{Perimeterial distance} = \frac{1.2}{0.6} = 2 \text{ m}$$

$$\text{i.e. } \pi d = 2$$

$$\text{or } d = 0.64 \text{ m.} = 640 \text{ mm.}$$

Diameter of the Suction Pipe:

$$0.176 = \frac{\pi}{4} d^2 \times v = \frac{\pi}{4} d^2 \times 1$$

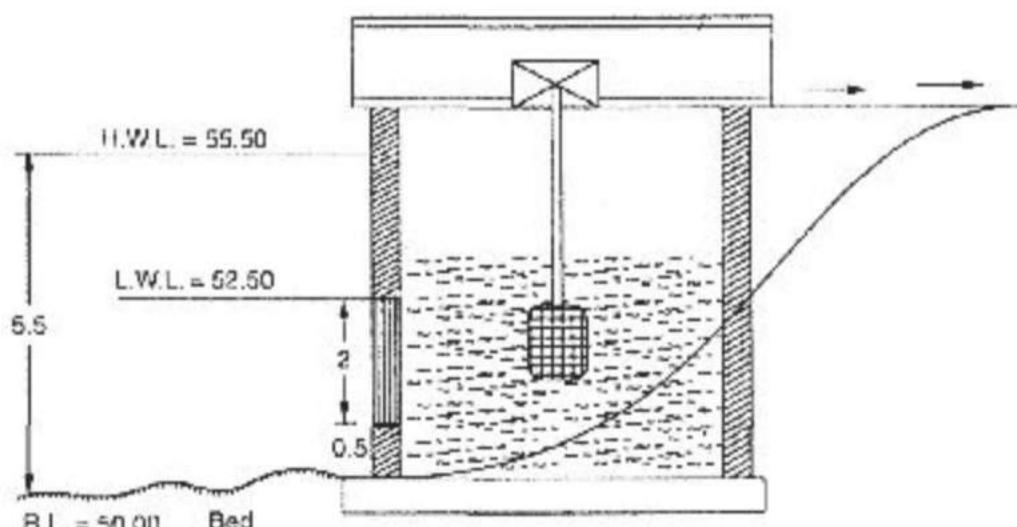
$$\Rightarrow d = \sqrt{\frac{0.176 \times 4}{\pi}} = 0.4731 = 0.5 \text{ m.}$$

\therefore Power required

$$= WQH$$

$$= 9810 \times 0.176 \times H \text{ (watt)}$$

$$= \frac{9810 \times 0.176 \times H}{746} \text{ (H.P.) (if efficiency is 100%)}$$



Design of canal intake:

1. Q and then assume D.T. and get volume of intake.
2. Design of coarse screen.
3. Design of bell mouth entry.
4. Design of intake conduit.
5. Head loss.

CONDUITS FOR TRANSPORTING WATER

Types of conduits:

1. Gravity conduits; and
2. Pressure conduits (Pressure above the atmospheric pressure)
 1. Gravity conduits;
 - (i) Canal (often used for irrigation)
 - (ii) Flumes
 - (iii) Aqueducts (are closed, rectangular, circular or horse shoe sections). They are generally designed as $\frac{1}{2}$ to $\frac{3}{4}$ th full.

- In gravity conduit, the hydraulic gradient line will coincide with the water surface and will be parallel to the bed of the conduit.
- These conduits cannot, therefore, go up and down hills and valleys as desired by existing topography of the area.
- From hydraulic point of view, a circular section provides the maximum hydraulic mean depth or maximum area per unit of wetted perimeter ($i.e. R = \frac{A}{P}$) and is, therefore, the most efficient. Moreover, since the perimeter per unit of cross section is less than the construction cost or material required is also the least. But circular sections cannot be easily supported on ground and, therefore seldom used.
- A rectangular shape is hydraulically inefficient and requires more material for construction, but is more stable to support on the ground, and therefore widely used.
- Horse shoe shape may be used with great advantage.
- The bed or the invert of the conduit in pressure flows is thus independent of the grade of the hydraulic gradient line which really governs the flow velocities.
- The pressure pipes can, therefore, 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 H.G. Lines and thus requiring lesser length of conduit.

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Head loss caused by pipe friction can be found by using either of the following formula:

1. Darcy Weisbach's formula:

$$H_L = \frac{f' LV^2}{2gd}$$

where f' = Dimensionless friction factor (average value = 0.024) depends upon Reynold number ($Re = \frac{V_d}{\nu}$) and relative roughness of the pipe (f).

The relative roughness ($f = \frac{2e}{d}$) of a pipe depends upon the absolute roughness (e) of the inside surface and the diameter of the pipe d .

- The approximate values of ' f' are given by the following empirical relations:

$$f = 0.04 \left(1 + \frac{1}{35d} \right) \text{ for old pipes}$$

$$= 0.02 \left(1 + \frac{1}{35d} \right) \text{ for new pipes}$$

- The accurate value of f' depends upon Re and f ; and may be given by a formula, such as

$$(i) f' = \frac{64}{Re} \text{ for laminar flow, i.e. upto } Re = 2000$$

$$(ii) (a) \frac{1}{\sqrt{f'}} = 2 \log_{10} Re \sqrt{f'} \\ - 0.8 \text{ for smooth pipes} \quad \left. \begin{array}{l} \text{above } Re = 400 \\ \text{turbulent flow is} \\ \text{fully established} \end{array} \right\}$$

$$(b) \frac{1}{\sqrt{f'}} = 2 \log_{10} \frac{d}{2e} \\ + 1.74 \text{ for rough pipes}$$

$$(c) f' = 0.005 + \frac{0.396}{Re^{0.3}} \text{ for smooth pipes } Re \\ \text{lies between } 2 \times 10^4 \text{ to } 2 \times 10^6$$

$$(d) f' = 0.0032 + \frac{0.221}{Re^{0.237}} \text{ for smooth pipes } Re \\ \text{lies between } 2 \times 10^4 \text{ to } 3.24 \times 10^6$$

$$(iii) \frac{1}{\sqrt{f'}} = 1.74 - 2 \log_{10} \left[\frac{2e}{d} + \frac{18.7}{Re \sqrt{f'}} \right]$$

Re lies between 2000 to 4000

Value of $2e$ cast iron = 300

Value of $2e$ concrete = 300 – 3000

2. Manning's formula: (generally used for gravity conduit)

Also applicable to turbulent flow in pressure conduits and yields good results.

$$H_L = \frac{n^2 V^2 L}{R^{4/3}}, \text{ where, } R = \frac{d}{4}$$

We know,

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Squaring

$$V^2 = \frac{1}{n^2} R^{4/3} S$$

Also,

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

∴

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

3. Hazen-William's formula: Widely used for pipe flow

$$\text{Flow velocity, } V = 0.85 C_H R^{0.63} S^{0.54}$$

where, C_H = Coefficient of hydraulic capacity

= 130 for concrete

= 130 for cast iron (new)

= 120 for cast iron (old)

$$R = \text{Hydraulic mean depth} = \frac{d}{4}$$

$$S = \text{Slope of the energy line} = \frac{H_L}{L}$$

- The flow velocities are normally kept between 0.9 m/sec. to 1.5 m/sec. though velocities upto 3 m/sec. to 6 m/sec. can be resisted by the commonly available pipes or pipe materials.

- In smaller size pipes at equal velocities, the head loss is more. Hence the cost of pumping will be increased by using a smaller size pipe although the cost of the pipe itself will be reduced.

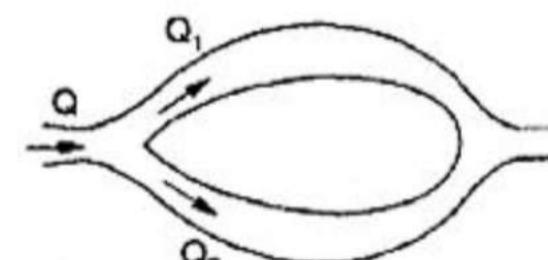
- Break horse power of pumps,

$$H.P. = \frac{WQH}{75\eta} = \frac{1000 \times Q \times H}{75 \times \eta}$$

where, η = efficiency of pump set.

FLOW IN PIPE SYSTEMS

- When the pipes are parallel; the head loss through each pipe will be different.



Applying continuity equation.

$$Q = Q_1 + Q_2$$

- When the pipes are in series, the total head loss is equal to the summation of the individual head losses in different pipes.

- The minor losses are represented as k_1 , $\frac{V^2}{2g}$

ANALYSIS OF COMPLEX PIPE NETWORKS

In any pipe network, the following two conditions must be satisfied:

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

Based upon these two basic principles, the pipe networks are generally solved by the methods of successive approximation, because any direct analytical solution is not possible, as the same will involve various equations to be solved simultaneously and many of which are nonlinear.

Important methods used for such solutions are:

1. Hardy-Cross Method

The procedure suggested by Hardy and Cross requires that the flow in each pipe is assumed by the designer (in magnitude as well as direction) in such a way that the principle of continuity is satisfied at each junction (i.e. the inflow at any junction becomes equal to the outflow at that junction).

A correction to these assumed flows is then computed successively for each pipe loop in the network, until the correction is reduced to an acceptable magnitude.

If Q_a is the assumed flow and Q is the actual flow in the pipe, then

$$\text{Correction, } \Delta = Q - Q_a$$

$$\text{or } Q = Q_a + \Delta$$

$$\text{or } \Delta = -\frac{\Sigma k \cdot Q_a^x}{\Sigma x \cdot k Q_a^{x-1}}$$

Since Δ is given the same sign (or direction) in all pipes of the loop, the denominator of the above equation is taken as the absolute sum of the individual items in the summation.

$$\therefore \Delta = -\frac{\Sigma k \cdot Q_a^x}{\Sigma |x \cdot k Q_a^{x-1}|}$$

$$\text{or } \Delta = \frac{-\Sigma H_L}{x \cdot \Sigma \left| \frac{H_L}{Q_a} \right|}$$

where H_L = head loss for the assumed flow Q_a

2. Equivalent Pipe Method

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

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

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

FORCES ACTING ON PRESSURE CONDUITS

Internal pressure of water: The maximum internal pressure likely to come under worst circumstances is usually taken equal to the sum of full static pressure and the water hammer

pressure.

Total maximum internal pressure

$$= \text{Static pressure} + \text{Water hammer pressure.}$$

$$P = P_s + P_h$$

$$\text{Due to this hoop stress developed, } \sigma = \frac{Pd}{2t}$$

1. Water hammer Pressure:

It is the pulsation of pressures above and below the operating pressure, resulting from the pressure wave, caused by sudden closure of a discharge valve. The sudden acceleration/ deceleration of the velocity of water caused by such a pressure wave, exerts a force, which is absorbed largely by the elastic properties of water, and partly by the elastic properties of the pipe material.

The maximum water hammer pressure is developed when the valve is quickly or instantaneously closed.

$$(P_h) \text{ maximum } = \rho_w U_p V \quad \dots(i)$$

where, U_p = velocity of the pressure wave generated.

V = velocity of water in the pipe (V to 0)

When the elasticity of pipe material is also considered, then velocity of pressure wave

When the elasticity of pipe is ignored, then velocity of the pressure wave

$$U_p = \sqrt{\frac{E_w}{\rho_w}} \frac{1}{\sqrt{1 + \frac{E_w}{E_p} \times \frac{d}{t}}} \quad \dots(ii)$$

where, E_w = Modulus of elasticity of water or bulk modulus of compression of water

E_p = Modulus of elasticity of pipe material

d = Diameter of the Pipe

t = Thickness of the pipe shell.

ρ_w = Density of the water.

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From equations (i) and (ii),

$$\rho_h \text{ maximum} = \rho_w \sqrt{\frac{E_w}{\rho_w}} \frac{1}{\sqrt{1 + \frac{E_w}{E_p} \times \frac{d}{t}}} \cdot V$$

where $\sqrt{\frac{E_w}{\rho_w}}$ = velocity of sound in water or sonic velocity = 1433 m/sec.

$$P_h \text{ (maximum)} = \frac{14.6 V}{\sqrt{1 + \frac{k_d}{t}}} \text{ kg/cm}^2$$

where,

$$k = \frac{E_w}{E_p} = \frac{\text{Modulus of elasticity of water}}{\text{Modulus of elasticity of pipe material}}$$

- Value of E for water = 2100 MPa $\approx 0.02 \times 10^5$ MPa

E_p for steel = 2.1×10^5 MPa $\approx 2 \times 10^5$ MPa

E_p for cast iron = 1.05×10^5 MPa $\approx 1 \times 10^5$ MPa

E_p for concrete = 0.21×10^5 MPa $\approx 0.2 \times 10^5$ MPa

Thickness of metal pipe for safe design against internal pressure of water.

$$t = \frac{1}{\eta} \frac{Pd}{\sigma_{st}}$$

where, P = internal pressure of water

η = efficiency of joint

Critical Time: If the valve is closed gradually, the time taken by the wave in going to the reservoir and coming back to the valve, is called **critical time**.

$$T_c = \frac{2s}{U_p}$$

where s is the distance of the valve from reservoir.

If the actual time of closure T is less than or equal to the critical time T_c , naturally full maximum water hammer will be developed.

If the actual closure time T is more than the critical time T_c full pressure is not developed.

$$P_h = P_h \text{ (maximum)} \left(\frac{T_c}{T} \right)$$

i.e. water hammer pressure can be considerably reduced by using slow closing valves.

2. Pressure due to external load :

External load transferred to the pipe are:

- weight of the backfill
 - super-imposed traffic load if any; and
 - self weight of pipe.
- For design consideration of pipe, internal pressure is considered zero. This is the worst condition.

- The stresses produced due to external loadings, at present, can be evaluated by using certain empirical formulas, as given below :

- For pipes resting on or projecting above the undisturbed ground in cohesionless soil and covered with fills the external load likely to come per unit length of pipe

$$W = C_p \gamma D^2$$

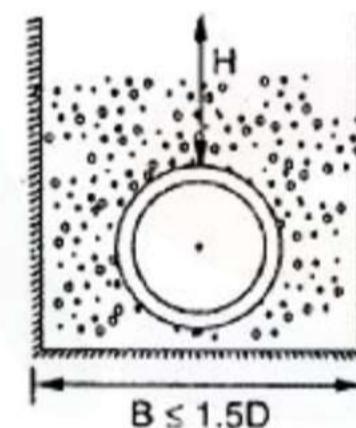
where, C_p = a coefficient find from Table.

γ = unit weight of the fill material.

D = external diameter of the pipe
 $= d_i + 2t$

- For flexible pipe (such as steel pipe) buried in narrow trench and thoroughly compacted side fills, the external load per unit length of pipe is given by

$$W = C \gamma BD$$



where, C = a coefficient find from Table.

D = external diameter of the pipe.

B = width of the trench $\leq 1.5D$

- For rigid pipes (such as concrete, cast iron, vitrified clay, etc.) buried in narrow trenches and thoroughly compacted with cohesion-less fills, the external load per unit length of the pipe is given by

$$W = C \gamma B^2$$

where, C , γ , B have the same meaning as given above.

- The amount of superimposed load (such as traffic load) which is transmitted to the pipe can be evaluated by using Boussineg's equation. Assuming fill surface to be horizontal

$$P_t = \frac{3Q}{2\pi} \frac{Z^3}{R^5}$$

where, P_t = unit pressure developed at any point in the fill at a depth Z below the surface due to traffic load.

Q = superimposed load

R = slant height of the considered point from the load Q .

Z = distance of the top of pipe below the surface of the fill.

- The total traffic load developed on a unit length of conduit (w') can't be found by integrating above equation over the projected area of the pipe.
- The effect of superimposed load increases rapidly as the depth of cover increases (because Z^5 increases much more than H^3)

Total load per unit length of pipe

$$\begin{aligned} &= \text{Load coming from backfill} \\ &\quad + \text{load coming from traffic} = W + W' \end{aligned}$$

- Compressive stress produced, which should be checked when the pipe is empty will then be

$$= \frac{W + W'}{t} \text{ kg/m}^2$$

- γ for dry sand = lkN

4. Stresses due to flow around bends and changes in cross-section:

Free body diagram of water

Apply Newton's second law of motion

Net external force = Rate of change of momentum.

$$\Sigma F_x = \rho Q (V_2 \cos \theta - V_1)$$

$$\therefore P_1 A_1 - F_x - P_2 A_2 \cos \theta = \rho Q (V_2 \cos \theta - V_1)$$

$$\text{and } \Sigma F_y = \rho Q (V_2 \sin \theta - 0)$$

$$\therefore F_y - P_2 A_2 \sin \theta = \rho Q (V_2 \sin \theta)$$

$$\text{Resultant force, } F = \sqrt{F_x^2 + F_y^2}$$

These forces F_x and F_y and their resultant are the forces which are transmitted from the water to the pipe. An equal and opposite force must, therefore, be developed in the form of stresses in the pipe wall.

5. Flexural stress:

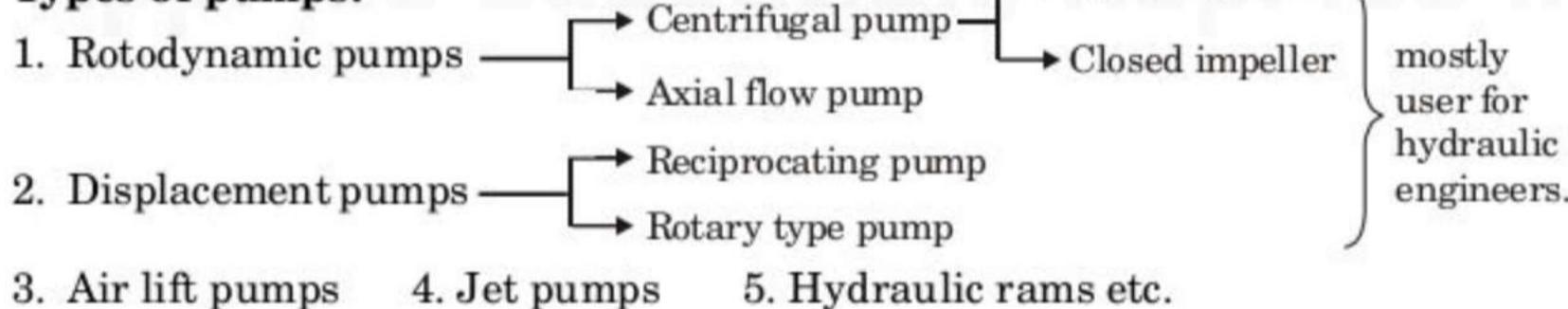
(i) **Working Pressure** – Defined as actual maximum pressure.

(ii) **Design Pressure** – Product of working pressure \times Factor of safety.

(iii) **Test Pressure**

PUMPS FOR LIFTING WATER

Types of pumps:



- Radial flow and mixed flow machines are commonly called **centrifugal pumps**, whereas the axial flow machines are called **axial flow pumps**.
- The efficiency of the "open impeller centrifugal pump" is generally much less than that of a **"closed impeller centrifugal pumps"**. But however, since the "open impeller" is less likely to be clogged by debris, etc. It is usually adopted for pumping raw water or sewage containing solids and other impurities.
- Impellers are placed in casing.

3. Temperature Stress:

When pipes are laid above the ground, then due to change in temperature expansion and contraction takes place and longitudinal stresses are produced in the pipe materials.

$$\delta = L \alpha T$$

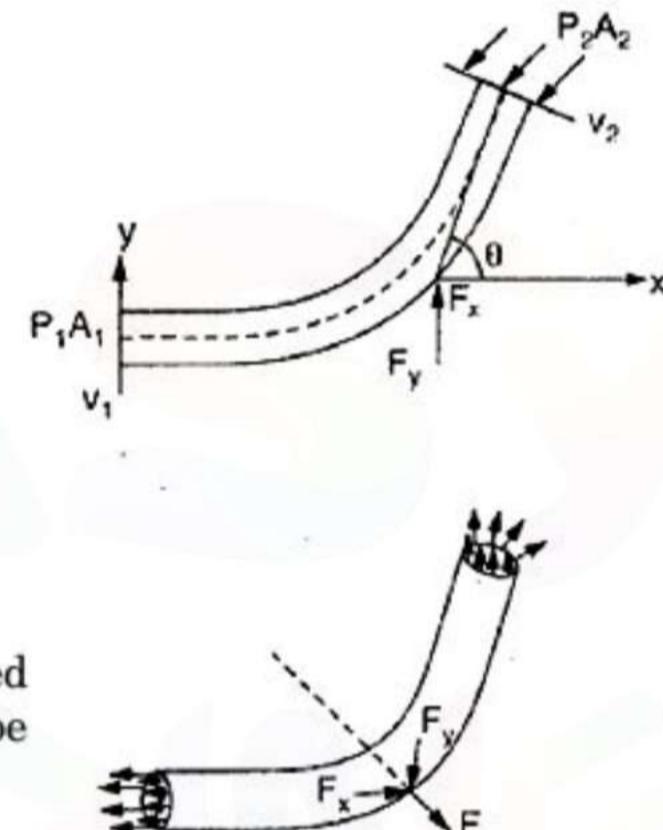
$$\epsilon = \frac{\delta}{L} = \alpha T$$

$$\sigma = E_p t = E_p \alpha T$$

where, E_p = Modulus of elasticity of pipe material.

α = co-efficient of expansion of the pipe material = $11 \times 10^{-6}/^\circ\text{C}$

T = change in temperature in $^\circ\text{C}$.



- In the case of bore hole pump, such as a deep well turbine pump, used for pumping ground water (sub-surface water), several impellers are installed on a vertical shaft, which is suspended and rotated from the prime mover motor placed at the ground surface.

Priming and operation of centrifugal pump:

A centrifugal pump may have to be primed before it is started. The priming consists in filling the pump casing with water, so that the air trapped in the pump does not hinder its operation to reduce its efficiency.

Characteristics of centrifugal pumps:

A typical characteristic curves are the curves obtained by plotting at constant speed (N).

- These curves provide the following important conclusions and consideration which are helpful while selecting a particular pump for a particular use.
- (i) As the discharge increases, the head produced decreases.
- (ii) The maximum efficiency is obtained at a particular discharge or at a particular use.

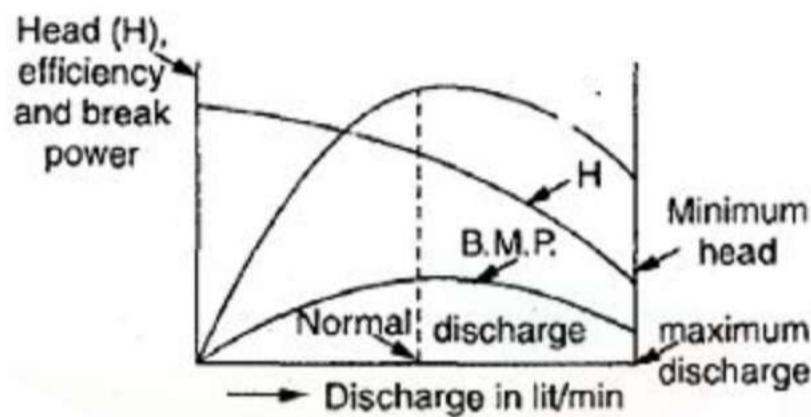


Fig. variation of head, efficiency, and break horse power, against the corresponding rate of discharge.

- In water supply schemes, where water demand is variable through out the day and year, several pumps of smaller capacities in parallel are used so that a variable number may be operated at capacity, depending on the flow requirements. With this arrangement, it is possible to operate all the pumps near the maximum efficiency or sometimes all the pumps are operated at full capacity, and the excess water during the period of less demand is stored in the "service reservoir" and utilised during high demand periods, (when demand rate exceeds the rate of pumping).

Specific speed (N_s) :

Specific speed of a centrifugal pump is defined as the speed at which a pump will discharge a unit flow under a unit head at maximum efficiency.

$$N_s = 51.66 \left[N \cdot \frac{Q^{1/2}}{H^{3/4}} \right]$$

where, Q and H are at maximum efficiency for the given speed N.

Q is in cumecs.

H is in metres.

N and N_s in rpm.

If N_s = 1000 to 4000, radial flow centrifugal pump is used.

If N_s = 4000 to 7000, mixed flow centrifugal pump is used.

If $N_s > 7000$, axial flow centrifugal pump is used.

Air lift pump:

Air lift pumps are generally used for pumping water from deep wells.

- The effectiveness of an air lift pumps is generally measured by a factor called **percentage submergence**.

Percentage submergence

$$= \frac{\text{Depth of submergence } (D_s) \times 100}{\text{Depth of submergence } (D_s) + \text{Effective lift of pump } (H_e)}$$

- $(D_s + H_e)$ represents the effective length of suction pipe.

Head, Power and Efficiency of Pump:

The total head (H) against which a pump has to work consists of

- suction lift (H_s);
- delivery head (H_d); and
- head lost due to friction, entrance and exit in the rising main (H_L).

$$H = H_s + H_d + H_L$$

- The work done by the pump in lifting Q cumecs of water by a head H = WQH kg. m/sec.
- The water horse power of the pump,

$$\text{W.H.P.} = \frac{\text{WQH}}{75}$$

- If η is the efficiency of the pump set, then the **Break horse power** of the pump (B.H.P) is given by

$$\text{B.H.P.} = \frac{\text{WQH}}{75\eta}$$

Economical diameter of the pumping mains

Economical diameter in metres, $D = 0.97 \text{ to } 1.22 \sqrt{Q}$
where, Q = discharge to be pumped in cumecs.

QUALITY CONTROL OF MUNICIPAL AND INDUSTRIAL WATER SUPPLIES

Characteristics of water

The raw or treated water can be checked and analysed by studying and testing their physical, chemical and microscopical characteristics as explained below :

Physical Characteristics:

This includes tests for determining

- Turbidity
- Colour
- Taste or odour
- Temperature
- Specific conductivity, etc.

(i) **Turbidity:**

The turbidity is measured by a turbidity rod or by a turbidimeter with optical observations, and is expressed as the amount of suspended matter in mg/lit or parts per million (ppm).

- For water, ppm and mg/lit are approximately equal.
- The standard unit is that which is produced by one milligram of finely divided silica (Fuller's earth) in one litre of distilled water.

Turbidimeters :

- (a) **Turbidity rod:** The turbidity can be easily measured in the field with the help of a turbidity rod. It consists of an aluminium rod which is graduated, as to give the turbidity directly in **silica** units (mg/lit)
- (b) **Turbidimeter:** The turbidity can be measured in the laboratory with the help of instruments called turbidimeter. In general, a turbidimeter works' on the principle of measuring the interference caused by the water sample to the passage of light rays.
- (c) **Jackson's candle turbidimeter:** The height of water column will therefore, be more for less turbid water; and vice versa. Longer the light path lower the turbidity. Such a turbidimeter cannot measure turbidities lower than 25 JTU. It can be used for natural source only, and it cannot be used to measure the turbidities of treated supplies, for which **Baylis's turbidimeter or modern nephelometers are used.**
- (d) **Baylis's turbidimeters :** One of the two glass tubes, is filled with water sample (whose turbidity is to be measured) and the other is filled with standard water solution of known **turbidity**. The electric bulb is lighted and the blue colour in both the tubes is observed from the top of the instrument.
- (e) **Modern Nephelometer:** For low turbidity less than 1 unit

NTU - Nephelometric Turbidity Units

FTU - Formazin Turbidity Units

(f) **Ratio turbidimeter**

- River water has maximum amount of **Turbidity**.

(ii) **Colour:**

The presence of colour in water is not objectionable from health point of view; but may spoil the colour of the clothes being washed.

- The standard unit of colour is that which is produced by one milligram of platinum cobalt dissolved in one litre of distilled water.

- For public supplies, the colour number on cobalt scale should not exceed 20, and should be preferably be less than 10.
- Colour determined by an instrument is known as tintometer.

(iii) **Taste and Odour:**

The extent of taste or odour present in a particular sample of water is measured by a term called **odour intensity**, which is related with the **threshold odour** or **threshold odour number**.

- Water to be tested is, therefore, gradually diluted with odour free water, and the mixture at which the detection of odour by human observation is just lost, is determined. The number of times the sample is diluted, represents the threshold odour number.
- For public supplies, the water should generally be free from odour, i.e. the threshold number should be 1 and should never exceed 3.

(iv) **Temperature:**

For potable waters, temperature of about 10°C are highly desirable. It should not be more than 25°C.

(v) **Specific Conductivity :**

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

CHEMICAL CHARACTERISTICS:

This includes tests for determining.

- (i) Total solids and suspended solids;
- (ii) pH value of water
- (iii) Hardness of water
- (iv) Chloride content
- (v) Nitrogen content.
- (vi) Metals and other chemical substances; and
- (vii) Dissolved gases.

(i) **Total solids and Suspended solids:**

- Total solids (suspended solid + dissolved solid) can be obtained by evaporating a sample of water and weighing the dry residue left and weighing the residue left on the filter paper.
 - The suspended solid can be found by filtering the water sample.
- Total permissible amount of solid in water is generally limited to 500 ppm.

(ii) **pH value of water:**

$$\text{pH} = -\log [\text{H}^+] = \log \left[\frac{1}{\text{H}^+} \right]$$

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If H^+ concentration increases, pH decreases and then it will be acidic.

If H^+ concentration decrease, pH increases and then it will be alkaline

- $[H^+] [OH^-] = 10^{-14}$
- $pH + pOH = 14$
- If the pH of water is more than 7, it will be alkaline, and if it is less than 7, it will be acidic.
- Generally speaking the alkalinity is caused by the presence of bicarbonate of calcium and magnesium; or by the carbonates or hydroxides of sodium, potassium, calcium and magnesium.
- Some, but not all of the compounds that cause alkalinity also cause hardness.
- The pH value of water can be measured quickly and automatically with the help of a **Potentiometer**.
- The pH can also be measured by indicators.

Indicator	pH range	Original colour of indicator dye	Final colour produced by water
Methyl orange	2.8 – 4.4	Red	Yellow
Methyl red	4.4 – 6.2	Red	Yellow
Phenol red	6.8 – 8.4	Yellow	Red
Phenolphthalein red	8.6 – 10.3	Yellow	Red

- Permissible pH value for public supplies may range between 6.6 to 8.4.
- The lower value of pH cause tuberculation and corrosion.
- The higher value of pH may cause incrustation, sediment deposits, difficulty in chlorination.

(iii) Hardness of water:

- Hard waters are undesirable because they may lead to greater soap consumption, scaling of boilers, causing corrosion and incrustation of pipes, making food tasteless etc.
- If bicarbonates and carbonates of calcium and magnesium are present in water, the water is rendered hard temporarily as this hardness can be removed to some extent by simple boiling or to full extent by adding lime to water. Such a hardness is known as **temporary hardness** or **carbonate hardness**.
- If sulphates, chlorides and nitrates of calcium or magnesium are present in water, they cannot be removed at all by simple boiling and therefore, such water require special treatment for softening. Such a hardness is known as permanent hardness or **non carbonate hardness**.

It is caused by Sulphates, Chlorides, Nitrates of Ca and Mg.

Measurement of hardness; (EDTA method) :

Total hardness (T.H.) in mg/l as $CaCO_3$ is

$$= \left[Ca^{+2} \text{ in mg/l} \times \frac{\text{Combine weight of } CaCO_3}{\text{Combine weight of } Ca^{+2}} \right. \\ \left. + [Mg^{+2} \text{ (mg/l)} \times \frac{\text{Combine weight of } CaCO_3}{\text{Combine weight of } Mg^{+2}}] \right]$$

$$\begin{aligned} \text{Combine weight of } Ca^{+2} &= 20 \\ \text{Mg}^{+2} &= 12 \\ \text{and } CaCO_3 &= 50 \end{aligned}$$

Carbonate hardness

$$= \left[\begin{array}{l} \text{Total hardness} \\ = \text{Alkalinity} \end{array} \right] \rightarrow \text{whichever is less}$$

$$\text{Non-carbonate hardness} = \text{Total hardness} - \text{Alkalinity.}$$

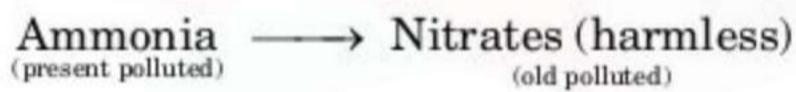
- Carbonate hardness is equal to the total hardness or alkalinity, whichever is lesser.
- Non-carbonate hardness is the total hardness in excess of the alkalinity. If the alkalinity is equal to or greater than the total hardness, there is no non-carbonate hardness.
- One French degree of hardness is equal to 10 mg/l of $CaCO_3$.
- One British degree of hardness is equal to a hardness of 14.25 mg/l.
- Water with hardness upto 75 ppm are considered soft and above 200 ppm are considered hard. In between moderately hard.
- Underground waters are generally harder than the surface waters.
- The prescribed hardness limit for public supplies ranges between 75 to 115 ppm.

(iv) Chloride content:

- The chloride content of treated water to be supplied to the public should not exceed a value of about 250 ppm.
- The chloride content of water can be measured by filtrating the water with standard silver nitrate solution using potassium chromate as indicator.

(v) Nitrogen content:

- The presence of nitrogen in water may occur in one or more of the following forms:
 - Free ammonia:** It indicates very first stage of decomposition of organic matter. It should not exceed 0.15 mg/l.
 - Albuminous or Organic matter:** It indicates the quantity of nitrogen present in water before the decomposition of organic molten has stated. It should not exceed 0.3 mg/l.
 - Nitrites:** Not fully oxidised organic matter in water.
 - Nitrates: It indicates fully oxidised organic matter in water (representing old pollution).



- Nitrites is highly dangerous and therefore the permissible amount of nitrites present in potable water should be nil.
- Ammonia nitrogen + organic nitrogen = kjedhal nitrogen
- Nitrates in water is not harmful. However the presence of too much of nitrates in water may adversely affect the health of infants, causing a disease technically called "**methemoglobinemia**" commonly called "**blue baby disease**".
- The nitrate concentration in domestic water supplies is generally limited to 45 mg/l.
- In old days, nitrogen tests were considerable importance, as they were the only methods for detecting pollution caused by sewage or organic waste and thus indicating the presence or absence of bacteria and other such pollutants.

(vi) Metals and other chemical substances:

Iron	- 0.3 ppm	Excesses of these cause discolouration of clothes.
Maganese	- 0.05	
Copper	- 1.3	
Sulphate	- 250	
Fluoride	- 1.5	

Excess affect human lungs and other respiratory organs.

- A fluoride concentration of less than 0.8-1.0 ppm cause dental cavity (tooth decay). If fluoride concentration is greater than 1.5 ppm, causing spotting and discolouration of teeth (a disease called **fluorosis**).

(vii) Dissolved Gases:**Gases present are :**

N ₂	CH ₄ ,	H ₂ S,	CO ₂	and	O ₂
	explosive	bad taste odour	corrosion biological activity		useful and necessary (D.O.)

Oxygen gas is generally absorbed by water from the atmosphere, but it being consumed by unstable organic matter for their oxidation. Hence, if the oxygen present in water is found to be less than its saturation level, it indicate presence of organic' matter and consequently making the waters suspicious.

- The extent of organic matter present in water sample can be estimated by supplying oxygen to this sample and finding the oxygen consumed by the organic matter present in water. This oxygen demand is known as **Biological oxygen demand (BOD)**.
- It is not practically possible to determine ultimate oxygen demand. Hence, BOD of water during the first five days at 20°C is generally taken as the standard demand.

$$\text{BOD}_5 = \text{BOD of 5 days} = \text{Loss of oxygen in mg/l}$$

$$\times \text{Dilution factor.}$$
- The BOD of safe drinking water must be nil.

BACTERIAL and MICROSCOPICAL CHARACTERISTICS:

Five types of parasitic organisms (viz. bacteria, protozoa, viruses, worms and fungi) are generally known to be infective to man and are found in water.

- Bacteria:** These are the minute single cell organisms possessing no defined nucleus and having no green material to help them manufacture their own food. They are reproduced by binary fission and may be of various shapes, and sizes are 1 to 4 microns, examined by microscope.
- Non-disease** causing bacteria - Non pathogenic bacteria.
- Disease causing bacteria known as - Pathogenic bacteria.
- Protozoa:** These are single cell animals and are the lowest and the simplest form of animal life. They are bacteria eaters and thus destroy Pathogens. They are directly counted by microscope.
- Worms** are the larva of flies
- Fungi** are those plants which grow without sunlight and live on other plants or animals, dead or alive.

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Classification Based on the oxygen requirements of the bacteria:

- (i) Aerobic bacteria : Those which require oxygen for their survival
- (ii) Anaerobic bacteria : Those which flourish in the absence of free oxygen.
- (iii) Facultative bacteria : Those which can survive with or without free oxygen.

Pathogenic bacteria can be tested and counted in the laboratories but with great difficulty. These tests are therefore, generally not performed in routine to check up of the water quality. The usual routine tests are generally conducted to detect and count the presence of **coliforms** which in themselves are **harmless organisms**, but their presence or absence indicates the presence or absence of pathogenic bacteria.

Methods to measure the presence of coliform bacteria:

- (i) Membrane filter technique (Modern Technique).
- (ii) Mixing different dilution of a sample of water with lactose froth and incubating them in test-tubes for 48 hours at 37°C. The presence of acid or carbon dioxide gas in tubes will indicate the presence of coliform bacteria.
- Most probable number (MPN) represent the bacterial density.

(iii) Coliform index:

It may be defined as the reciprocal of the smallest quantity of a sample which would give a positive

portion. Coliform sometimes, called bacteria coli (B-colil) or Escherichia coli (Ecoli) are harmless aerobic micro-organisms.

- If not more than 1 coliform colony is present per 100 ml. of water, then water is said to be safe for drinking.

$$\bullet \text{ MPN/100 ml.} = \frac{100 \times \text{Number of Positive Portion}}{\sqrt{(\text{ml. in all negative portion})}} \\ \times (\text{ml. in all positive portion})$$

Water Borne Diseases and their control

Water borne diseases are those diseases which spread primarily through contaminated water.

Important water borne diseases:

1. Disease caused by bacterial infections:

- (i) Typhoid fever and paratyphoid fever (caused by salmonella typhi bacteria)
- (ii) Cholera (caused by vibrio-cholera bacteria)
- (iii) Bacillary dysentery (caused by shiga bacillus or flexner bacillus).

2. Disease caused by viral infections:

- (i) Infectious hepatitis or infectious jaundice (caused by hepatitis virus).
- (ii) Poliomyelitis (caused by polio virus).
- (iii) Gastroenteritis.

3. Disease caused by protozoal infections:

Amoebic dysentery (caused by entamoeba hystolytic germ).

WATER QUALITY STANDARDS FOR DRINKING WATER

S. No.	Type of Characteristic	Type of impurity	Permissible limit	Absolute maximum limit	Remark
1.	Physical	Turbidity	5	25	On silica scale
		Colour	5	50	Colour number on cobalt scale
		Taste & odour	1	3	Threshold odour number
2.	Chemical	pH value	7-8.5	6.5-9.2	
		Hardness	75 mg/l	110 mg/l	Hardness expressed as CaCO.
		Total solids	500 mg/l	1500 mg/l	As per WHO standards
		Magnesium & Sodium	500	1000 mg/l	As per WHO standards
		Chlorides	200	600 mg/l	As per WHO standards
		Sulphates	200	400 mg/l	As per WHO standards
		Calcium	75	200 mg/l	As per WHO standards
		Zinc	5	15 mg/l	As per WHO standards
		Copper	1	1.5 mg/l	As per WHO standards
		Iron	0.3	1.0	As per WHO standards
		Manganese	0.1	0.5	As per WHO standards
		Arsenic	Nil	0.2	As per WHO standards
		Lead	Nil	0.1	As per WHO standards
		Selenium	Nil	0.05	As per WHO standards
		Chromium	Nil	0.05	As per WHO standards
		Phenolic compounds			

S. No.	Type of Characteristic	Type of impurity	Permissible limit	Absolute maximum limit	Remark
		as phenol	0.001	0.002	As per WHO standards
		Cynide	Nil	0.01	As per WHO standards
		Fluoride	0.5 mg/l	1.5 mg/l	As per WHO standards
		Cadmium	-	0.05 mg/l	As per WHO standards
3.	Biological and Micro-organic		Coliform bacteria	Nil colony per 100 ml. or MPN of B coli is limited to 1 per 100 ml.	1 coliform
4.	Radiological β-emitters	α-emitters	Nil	1 puc/litre	W.H.O. standard
			Nil	10 puc/litres.	W.H.O. standard

- Water used in pulp or paper industries, must be free from iron, manganese, and hardness.
- Water required for breweries, distilleries, and bakeries should preferably be hard.
- For steel rolling mills, the chloride content of water must be less than 150 mg/l
- The Water (prevention and control of pollution) Act enacted by the Indian Parliament in 1974.

BIOCHEMICAL OXYGEN DEMAND :

If sufficient oxygen is present in the water, the useful aerobic bacteria production will flourish and cause the biological decomposition of waste and organic matter thereby reducing the carbonaceous material from the water. The amount of oxygen required in the process until oxidation gets completed is known as BOD.

PURIFICATION OF WATER SUPPLIES

Methods of Purification of Water

- Screening (Intake)
- Plain sedimentation
- Sedimentation with coagulation;
- Filtration
- Disinfection
- Aeration
- Softening; and
- Miscellaneous treatments, such as fluorination, recarbonation, liming, desalination. etc.

PLAIN SEDIMENTATION

- Principle behind sedimentation is to reduce the flow velocity by providing tank called **settling tank**, or **clarifier** or **sedimentation basin**.
- Theoretical average time for which the water is detained in the tank is called the detention period.
- The settling velocity of spherical particle,

$$V_s = \frac{g}{18} (G - 1) \frac{d^2}{v} \text{ for } d < 0.1 \text{ mm. [Re} < 0.5]$$

where, V_s = velocity of settlement of particle.

d = diameter of the particle.

G = specific gravity of the particle.

v = kinematic viscosity of water.

$$R_e = \text{Reynold number} = \frac{V_s d}{v}$$

Since, the viscosity depend upon temperature, the above equation can be modified as

$$V_s = 418(G - 1)d^2 \left(\frac{3T + 70}{100} \right) \text{ for } d < 0.1 \text{ mm.}$$

where, T = temperature of water in degree centigrades.

V_s = velocity of settlement in mm/sec
 d = diameter of the particle in mm.

$$V_s = 1.8\sqrt{gd(G - 1)}$$

for $d > 1.0$ mm (turbulent settling)

- In transition zone, settling velocity is given by Hazen as :

$$V_s = 418(G - 1)d \left(\frac{3T + 70}{100} \right) \text{ when } d \text{ lies between } 0.1 \text{ mm. and } 1 \text{ mm.}$$

The above formula represent the theoretical settling velocities of discrete spherical particles.

The actual settling velocities in the sedimentation basins, will be much less than that calculated by these formulae, because of:

- the non-sphericity of the particles,
 - the upward displacement of the fluid caused by the settling of other particles, and
 - convection currents.
- A plain sedimentation tank under normal conditions may remove as much as 70% of the suspended impurities present in water.

Types of sedimentation tank:

- (i) Intermittently function sedimentation tank - not preferred these day.
- (ii) Continuously function sedimentation tank.
- The velocity is so adjusted that the time taken by the particle to travel from one end to another is slightly more than the time required for settling of that particle.

DESIGN OF CONTINUOUS FLOW TYPE OF SEDIMENTATION TANK

- Flow velocity, $V = \frac{Q}{BH}$

where, Q = Discharge entering the basin,
 B = Width of the basin, and
 H = Depth of water in the tank.

- $\frac{V}{V_s} = \frac{L}{H}$

$$\Rightarrow V_s = \frac{VH}{L} = \frac{Q}{BH} \times \frac{H}{L} = \frac{Q}{BL}$$

$$\Rightarrow V_s = \frac{Q}{BL} = \text{Permissible velocity}$$

- It shows that all those particles having a settling velocity equal to or greater than $\frac{Q}{BL}$ will settle down and be removed.
- $\frac{Q}{BL}$, i.e. the discharge per unit of plan area (surface area) is a very important term for the design of continuous flow type settling tanks; and is known as the **overflow rate** or the **surface loading** or the **overflow velocity**.

Overflow velocity = 500 – 700 litres/hr./m² of plan area for plain sedimentation tanks and overflow velocity = 1000 – 1250 litres/hr./m² of plan area for plain sedimentation tanks using coagulants as aids.

- Smaller particles will also settle down, if the overflow rate is reduced.
- Usual values of depth ranges between 3.0 to 4.5 m.

Detention period or Retention period (t):

It is the average time for which the water is detained in the tank.

- Detention time for rectangular tank,

$$t = \frac{\text{Volume of the tank}}{\text{Rate of flow}}$$

$$\text{i.e. } t = \frac{BLH}{Q}$$

Detention time for a circular tank,

$$t = \frac{d^2(0.011d + 0.785H)}{Q}$$

where, d = Diameter of the tank.

H = Side water depth.

- Detention time = 4 to 8 hr. for plain sedimentation; and
 Detention time = 2 to 4 hr. when the coagulants are used.
- $B \approx 10$ to 12 m.
- Length of the tank is not generally allowed to exceed four times the width.
- Normally kept flow velocity at about 0.3 m./min.
- In actual practice, certain amount of short circuiting always exist and therefore, the actual average time which a batch of water takes is passing through a settling tank, is called the **flowing through period**.
- Displacement efficiency

$$= \frac{\text{Flowing through period}}{\text{Detention period}} \approx 0.25 \text{ to } 0.5$$

- For tanks without mechanical sludge removal equipment, an additional minimum depth of about 0.8 to 1.2 m. should be provided for storage of sediment, and is called the **sludge zone**.

SEDIMENTATION AIDED WITH COAGULATION

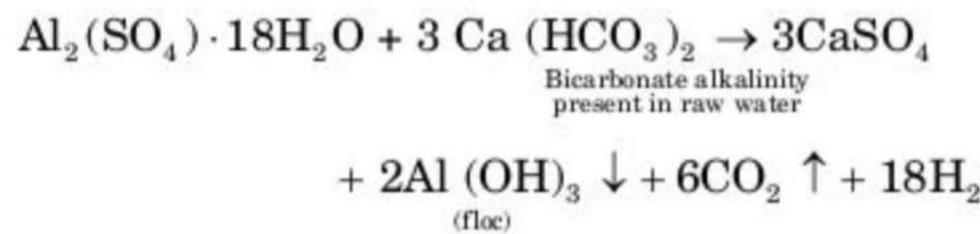
Certain chemical compounds called **coagulants** are added to the water, which on thorough mixing form a gelatinous precipitate called '**floc**'. The very fine mud particles and the colloidal matter present in water get attracted and absorbed in these flocs, forming the bigger sized flocculated particles. The process of addition and mixing of the chemicals (i.e., the coagulants) is called the **coagulation**. The coagulated water is then made to pass through the sedimentation tank, where the flocculated particles settle down and are thus removed.

The coagulation before sedimentation is almost universally adopted in all the major water treatment plants, and is followed by rapid sand filtration.

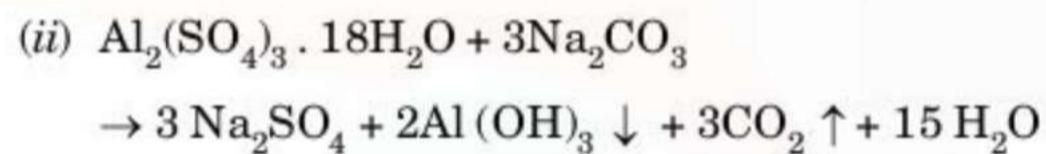
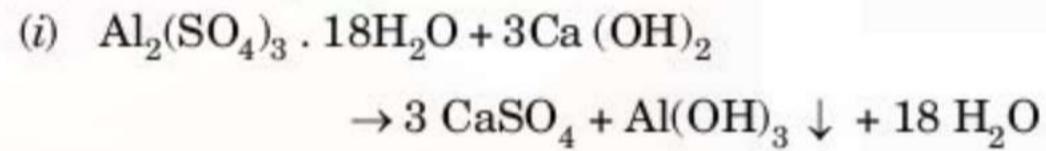
Chemicals used for coagulation:

- Aluminium sulphate, iron salts like ferrous sulphate, ferric chloride, ferric sulphate. These chemicals are most effective when water is slightly alkaline.

1. Aluminium sulphate



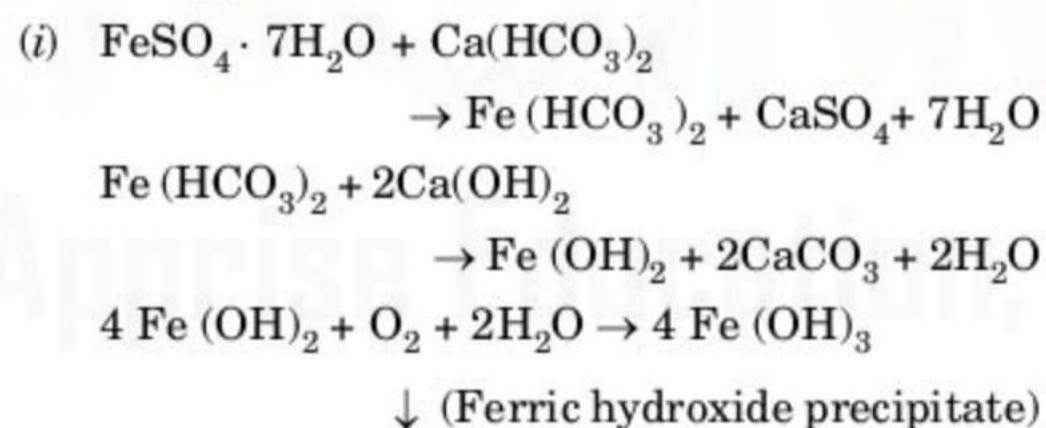
- Average normal does is about 17 mg/l (5 mg/l – 55 mg/l)
- If raw water supplies are not sufficiently alkaline, then the external alkalies like lime i.e. $\text{Ca}(\text{OH})_2$ or soda ash (Na_2CO_3) are generally added.



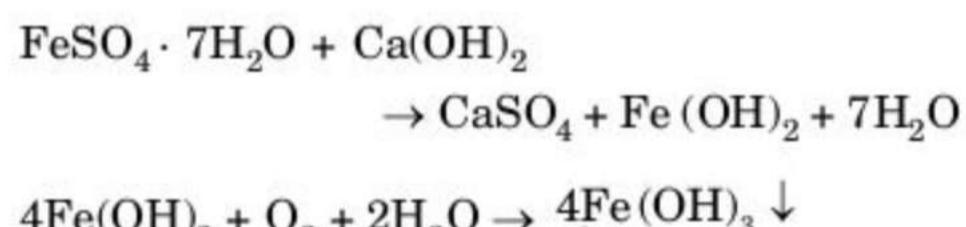
- Aluminium sulphate is very effective coagulant, and is now extensively used throughout the world.

2. Ferrous sulphate (copperas) ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$)

When copper as is added earlier to lime :

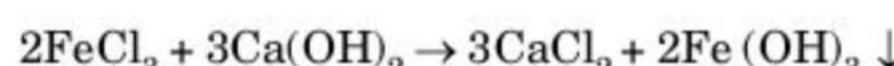
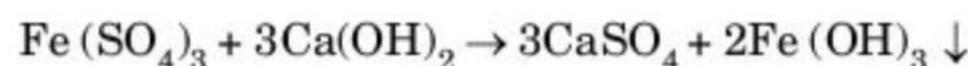
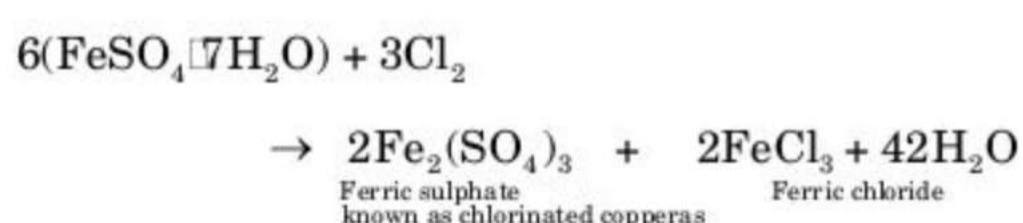


(ii) When lime is added first:



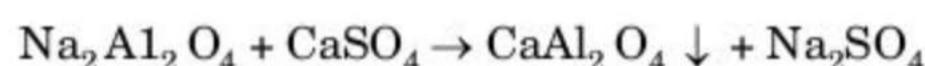
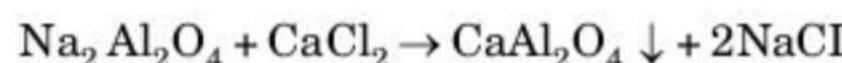
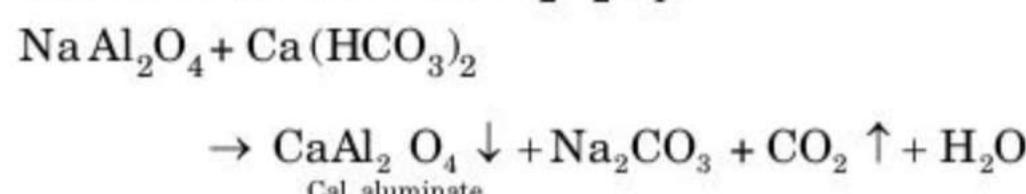
- Copperas are used when the raw waters are not coloured and high pH (8 to 10).

3. Chlorinated copperas



- It remove colour and effective in low & high pH range.

4. Sodium Aluminate ($\text{Na}_2\text{H}_2\text{O}_4$)



Iron salts are used as coagulants more frequently for treating sewage, and alum is used more frequently for treating raw water.

Parts of a Coagulation Sedimentation Plant

The coagulation sedimentation plant clariflocculator contains the following four units:

1. Feeding device;
 2. Mixing device or mixing basin;
 3. Flocculation tank or Flocculator; and
 4. Settling or sedimentation tank.
- The complete process of coagulation sedimentation may help in removing turbidities upto as low values as 10-20 mg/l. It may also help in reducing the bacteria from the water, and thus to reduce the B-col index by as much as 70%.
 - Large plant uses wet feeding while smaller plants uses dry feeding.

1. Feeding Device:

These are of two types:

- Dry feeding
- Wet feeding.

Feeding depends on following factors

- Characteristics of coagulant and convenience.
- Amount of coagulant
- Cost of coagulant and size of plan

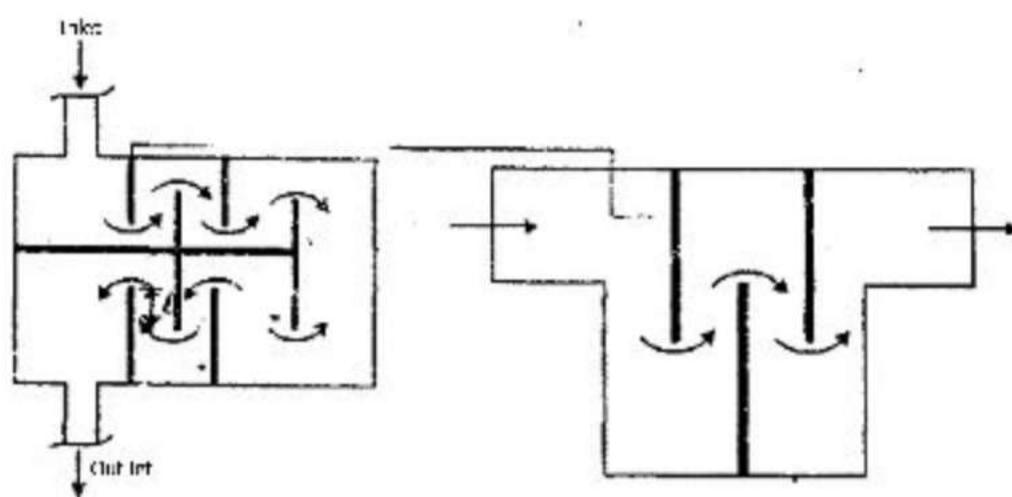
Note. Large plants use wet feeding and smaller plants use dry feeding, unless objected to by characteristics of coagulant.

2. Mixing Devices.

As Centrifugal pumps, compressed air, mixing basins etc.

MIXING BASINS

(a) With Baffle Walls



Design Criteria

Velocity of flow in channels = 1.15 to 0.045 m/sec.

Detention period = 20-50 min.

Hence length of flow is known.

The clear opening between end of each baffle and the tank wall should be kept about $1.5 \times$ distance between baffles.

minimum value = 60 cm

Note:

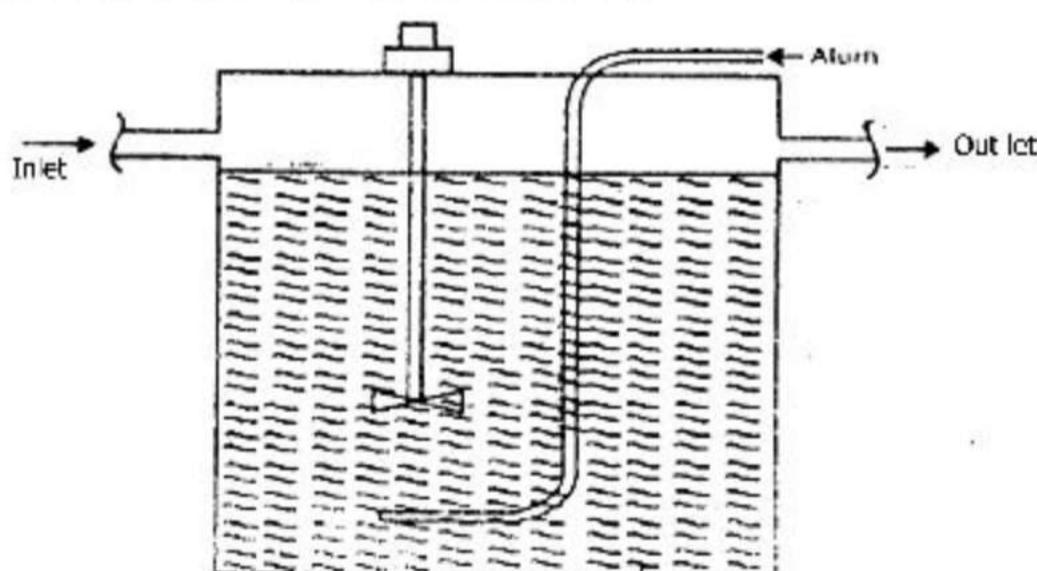
- (1) Around the end baffles should not be used when the computed depth < 1m.
- (2) In over and under baffles; depth is normally kept $(2 \text{ to } 3) \times$ distance between baffles.
- (3) In basins, loss of head $\approx 3.2 \times$ velocity head in channel
- (4) Baffle type mixing basins are not used in modern day or on large plants.

With Mechanical devices.

These use Flash Mixer

Impeller's speed = 100 - 120 rpm.

Detention period = 2-3 minutes.



Flocculator

Paddles rotated at speed of 2-3 rpm.

Detention period = 30 to 60 minutes (ave. 40 min.)

Clear distance between paddles and wall is about 15 to 30 cm.

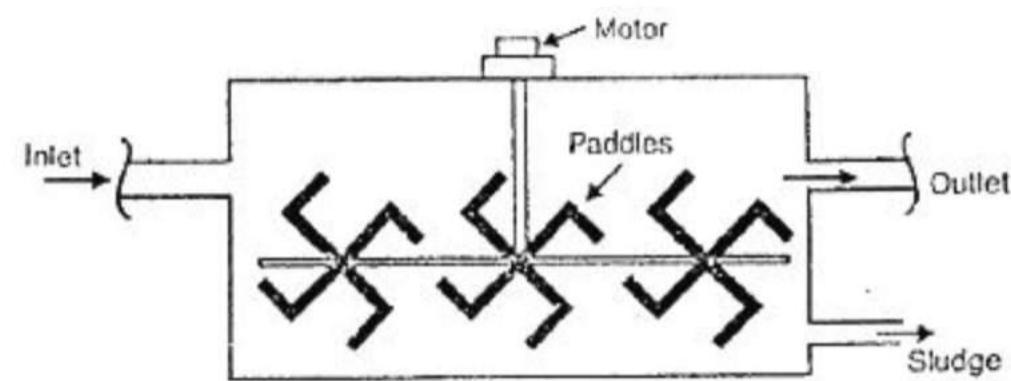


Fig. Flocculator

Sedimentation Tank

Detention period = 2 – 4 hrs.

Overflow rate = 1000 – 1250 lit/hr/m²

Combined Co-agulation-cum-Sedimentation Tank

Detention period = 15 – 40 in. floc-chamber, and 2-4 hrs. in settling tank

Optimum Coagulant Quantities Determination.

Jar test is made. Large number of jars are used for good results.

The amount of coagulant in jar which produces a good floc with the least amount of coagulant, indicates optimum dosage.

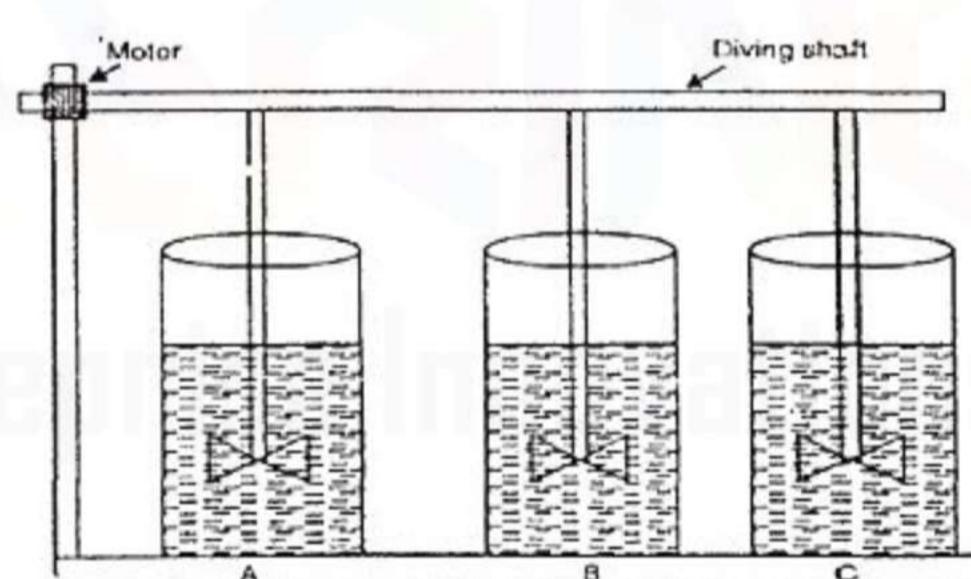


Fig. Jar Test

Production of Sludge

Alum, which is chiefly used has been found to be generating sludge equal to 0.24 times of its own weight.

Dry Sludge produced in mg/day = Q in lit/day [suspended solids removed in mg/l + 0.24 × Alum does in mg/l + misc. chemicals added like carbon, clay, polymer in mg/l]

Dewatering and Disposal of Sludge from Water Treatment Plants

Wet or watery sludge is produced in a water treatment plant in its following units :

- (i) Sedimentation flocculation tank or clariflocculator; and
- (ii) Filters

Methods for disposing of wastes obtained from above plants:

- (i) Ponding in artificial or natural lagoons
- (ii) Sand drying bed
- (iii) Gravity thickeners
- (iv) High speed centrifuges
- The dewatered sludge is finally disposed off either by incineration or by burial in trenches.

FILTRATION

The process of passing the water through the beds of granular materials is known as **Filtration**. Filtration may help in removing colour, odour, turbidity and pathogenic bacteria from the water.

Types of filters:

1. Slow sand gravity filters
2. Rapid sand gravity filters
 - Pressure filters are used for small plants such as for individual industrial supplies, not adopted for treating large scale municipal supplies.
 - Slow sand filters remove larger percentage of impurities and bacteria as compare to rapid sand filters but slow sand filters are obsolete these days due to slow rate of filtration.
 - In the modern treatment plants, rapid sand gravity filters are nowadays almost universally adopted. The water from the coagulation sedimentation plant is directly fed into the rapid sand gravity filters, and the resultant supplies are disinfected for complete killing of germs and colour removal.

SLOW SAND FILTERS

Construction of slow sand filters:

Parts of slow sand filter are:

1. **Enclosure tank or basin:** Depth of tank = 2.5 to 3.5 m.
Plan area of the tank = 100 to 2000 m²
2. **Filter media:** Sand layers go to 110 cm. in depth.

3. **Base material:** 30 to 75 cm. thick gravels of different sizes placed in layers.
4. Under drainage system.
5. Inlet and outlet arrangements.
6. Other appurtenances.

Rapid Sand Filters or Mechanical Sand Filters

These filters employ coarse sand, with effective size as 0.5 mm or so. On an average, these filters may yield as high as 30 times the yield given by the slow sand filters. Water from the clariflocculator are used in these filters, and filtered water is treated with disinfectants, so as to obtain potable supplies.

Construction of Rapid Gravity Filters

Parts of rapid sand filter are

1. **Enclosure tank or basin:** Depth of tank = 2.5 to 3.5 m.
Plan area of tank = 10 to 50 m² for each unit.
- Number of units at a filter plant

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

where, Q = Plant capacity in million litres per day.

2. **Filter media :** Sand layer 60 to 90 cm. in depth.
3. **Base material :** Gravel layer 60 to 90 cm. thick gravels of different sizes placed in layers.
4. Under drainage system
5. Other appurtenances.

Working and Cleaning of Rapid Gravity Filters:

- The amount of water required for washing a rapid gravity filter may vary from 21.5% of the total amount of water filtered. The rapid gravity filters get clogged very frequently and have to be washed every 24 to 48 hours.
- The rapid gravity filters are conventionally cleaned by back washing.

Rate of Filtration or Rate or Loading for Rapid Gravity Filters

3000 to 6000 litres/hr/m² of filter area.

Rate of filtration of pressure filter: 6000 to 15000 l/h/m² of filter media.

3000 to 6000 litres/hr/m² of filter area.

- The pressure filter are less efficient than the rapid gravity filter.
- Pressure filters are generally not used for treating municipal surface supplies.

Comparison of slow sand and Rapid sand filters:

S.No.	Item	Slow sand filters	Rapid gravity filters
1.	Pre treatment requirements	Effluents either from plain sedimentation tanks or raw waters without any treatment are generally fed into them; and coagulation is not at all required.	Coagulation, flocculation, and sedimentation is a must.
2.	Base material	The gravel base supports the sand. It varies from 3 to 65 mm in size and 30 to 75 cm. in depth.	The gravel base supports the sand and also distributes the wash water uniformly on the surface of sand. It varies from 3 to 40 mm. in size and its depth is slightly more, i.e. about 60 to 90 cm.
3.	Filter sand	The effective size (D_{10}) of filter sand ranges between 0.2 to 0.4 mm. and uniformity coefficient between 1.8 to 2.5 or 3.0. The grain size distribution is generally uniform throughout the depth of filter media, except that top 10 to 15 cm. may be laid of finer variety.	The effective filter sand ranges between 0.35 to as and uniformity coefficient between 1.2 to 1.8. The sand is laid in layers with smallest grain size at top and coarsest grain size at the bottom.
4.	Underdrainage system	Laid in order to receive filtered water.	Laid harder to receive filtered water and also to pass water for back washing at a very high rate.
5.	Size of each unit	Large such as (30 m to 60 m). The area varying from 100 to 2000 sq. m. or more.	Small, such as 5m × 8m. The area varying from 10 to 80 sq. m.
6.	Rate of filtration	Small such as 100 to 200 lit./hr./m ² of filter area.	Large such as 3000 to 6000 lit./hr./m ² of filter area.
7.	Economy	High initial cost of both land and material but low cost of operation and maintenance.	Low initial cost, but higher cost of operation and maintenance overall, it is cheaper & economical.
8.	Depreciation cost	Relatively low.	Relatively high.
9.	Efficiency	Very efficient in removing bacteria (98 to 99%) but less efficient in removing colour. Overall turbidity removal in these filters using plain sedimentation is also low. They cannot handle turbid water containing turbidities more than 50 mg/l.	Less efficient in removing bacteria (80 to 90%) but very efficient in removing colour. The overall turbidity removal in these filters using coagulation sedimentation, is also high. They can therefore, handle very turbid waters.
10.	Flexibility	Not flexible for meeting variations in demand.	Quite flexible for meeting reasonable variations in demand.
11.	Suitability and adaptability	May be adopted for treating smaller village supplies or for individual industrial supplies. They are absolute these day.	They are widely and almost universe adopted for treating public supplies especially at all major cities & town.
12.	Post treatment requirement, if any	Almost pure water is obtained. However, it may be disinfected slightly to make it completely safe. Other miscellaneous may or may not be required.	Disinfection is must and some other miscellaneous treatment may be given, if needed.
13.	Ease in construction	Simple	Complicated, as under drainage is properly designed.
14.	Skilled supervision, if required	Not required.	Essential.
15.	Method of cleaning	(a) Scrapping and removing the top 1.5 to 3 cm. thick layer and washing down by hoses. (b) Laborious method.	(a) Agitating the sand grains and back washing with or without compressed air. (b) Short and easy method.
16.	Period of cleaning	Cleaned at intervals of 1 to 3 months.	Cleaned frequently at intervals of 1 to 3 days.
17.	Loss of head	Approximately 10 cm is the initial loss, and 0.8 to 1.2 m is the final limit when cleaning is required	Approximately 0.3 m is the initial loss, and 2.5 to 3.5 m. is the final limit when cleaning is required.
18.	Quantity of wash water required	0.2 to 0.6% of the total water filtered	1 to 5% of the total water filtered

DISINFECTION OR STERILISATION

- Chlorine has been found to be the best and the most ideal disinfectant and is now invariably used throughout the world.
 - Disinfection means killing of only the disease producing bacteria, whereas sterilisation means killing of the bacteria of all types.
 - Disinfection, chlorination and sterilization are used as synonymous to each other.

Some Minor Methods of Disinfection.

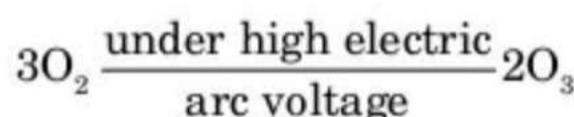
1. Boiling of water
 2. Treatment with excess lime
 3. Treatment with ozone
 4. Treatment with iodine and bromine
 5. Treatment with ultraviolet rays - suitable for swimming pool water
 6. Treatment with potassium permanganate; and
 7. Treatment with silver, called Eleipa-katadyn Process.

- 1. Boiling of water:** It can only kill the existing germs but cannot take care of the future possible contaminations, hence it is not used for disinfecting public supplies. However, during water borne epidemics, public is advised to drink water only after boiling.

2. Treatment with excess lime: Lime is generally used as a water purification plant for softening (i.e. reducing hardness), but excess lime may kill the bacteria also.

- The excess lime when added to water, in fact, raises the pH value of water.
 - This method is quite practical for complete removal of bacteria, yet needs the removal of excess lime from the water before it can be supplied to the general public (called recarbonation). Moreover, it cannot protect the water from the possible dangers of recontamination, and hence not used these days.

3. Treatment with Ozone:



- The nascent oxygen, so produced, is a powerful oxidising agent and removes the organic matter as well as the bacteria from the water.
 - Ozone being unstable, nothing remains in water, by the time it reaches the distribution system.
 - Ozone removes colour, taste and odour from water, in addition to removing the bacteria from it.

- The Ozonised water becomes tasty and pleasant unlike the chlorinated water which becomes bitter to tongue.

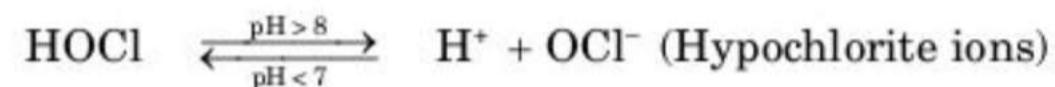
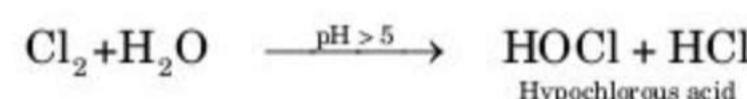
4. Treatment with Potassium permanganate ($KMnO_4$):

It is used for disinfecting well water supplies in village; which are generally contaminated with lesser amount of bacteria. It also produces taste.

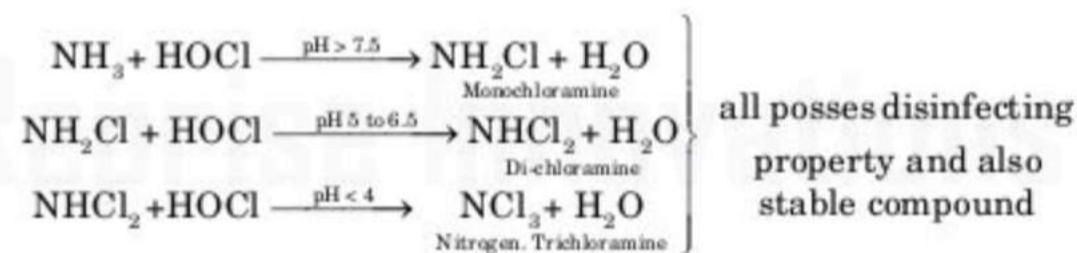
- If the pink colour disappears, it shows that organic matter is present in water.

CHLORINATION:

The treatment of water by called water is casual chlorination.



- The sum of hypochlorous acid, hypochlorite ions, and molecular chlorine existing in a sample of water is termed as **free available chlorine**.
 - Out of these form of free available chlorine, the hypochlorous acid is the most destructive, being about 80 times more effective than OCl. For this reason, the pH value of water during chlorination is generally maintained slightly less than 7, so as to keep the dissociation of HOCl to minimum and thereby keeping more HOCl in solution compared to OCL ions.
 - Moreover, the chlorine will immediately react with ammonia present in water to form various chloramines, as given below:



In usual chlorine treatment, when pH is kept slightly less than 7, NH_4^+ is the most predominant.

- If all NH_3 is consumed by added Cl_2 , then it would persist as free **chlorine**.
 - Chloramine is less effective than free chlorine.
 - Correct sequence of formation of residual chlorine compound is NH_2Cl , NHCl_2 , HOCl , OCl

Dose of Chlorine:

The amount of Cl_2 used in reducing organic and inorganic impurities is called the chlorine **demand of water**. After the Cl_2 demand is fulfilled, Cl_2 will appear as free chlorine residual (hypochlorites). This residue Cl_2 will serve as disinfectant to kill pathogens.

Chlorine does required for killing isolated virus:

Types of virus to be killed	Quantity of free chlorine required in mg/l with about 30 minutes contact period for water of pH lower than 7 or so.
Poliomyelitis Virus	0.1
Hepatitis Virus	0.4
Cysts of E. histolytica, i.e. the organism causing amoebic dysentery.	3.0 or even lower.
Tuberculosis organisms	3.0
Coxsaickie Virus	Very huge does varying from 21 to 138 mg/l

Various forms in which chlorine can be applied:

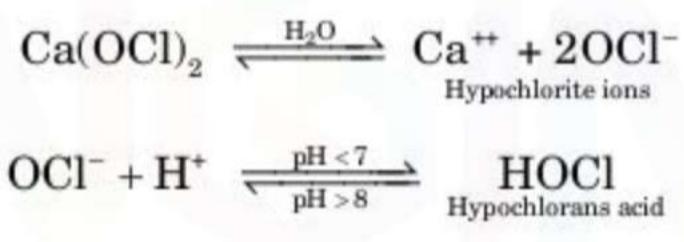
As free chlorine

In the form of liquid chlorine or as chlorine gas. (HOCl , OCl^-)

As combined chlorine

1. In the form of hypochlorites or bleaching power (Ca(OCl)_2)
2. In the form of chloramines, i.e. a mixture of ammonia and chlorine.
3. In the form of chlorine dioxide: Disinfecting power is $2\frac{1}{2}$ times stronger than chlorine but is very useful.

1. Use of Hypochlorites or Bleaching powder (not used these days)



This process is known as *hypochlorination*. The hypochlorite ions as well as hypochlorous acid both causing disinfection of water.

2. Use of chloramines or use of chlorine with ammonia:

Types of chlorination and certain important definitions:

- (i) Plain chlorination
 - (ii) Prechlorination
 - (iii) Postchlorination
 - (iv) Double chlorination
 - (v) Breakpoint chlorination
 - (vi) Super chlorination
 - (vii) Dechlorination
- (i) **Plain chlorination:** It indicates that only chlorine treatment and no other treatment has been given to the raw water.

The used quantity of chlorine required is about 0.5 mg/l or more

- (ii) **Pre-chlorination:** Pre-chlorination is the process of applying chlorine to the water before filtration or rather before sedimentation.

The normal doses are as 5 to 10 mg/l so that 0.1 to 0.5 mg/l of residual chlorine comes to the filter plant.

- (iii) **Post-chlorination:** It is the process of applying chlorine after filtration and before enter the distribution system. The dosage of chlorine should be such as to leave a residual chlorine of start 0.1 to 0.2 mg/l after a contact period of about 20 minutes. This residual will ensure the disinfection of water, if at all any future recontamination occurs in the distribution system.

- (iv) **Double chlorination :** It indicates that water has been chlorinated twice. The prechlorination and post-chlorination are generally used in double chlorination. Post chlorination, however, is generally always used, while the pre-chlorination is also used when the waters are highly turbid and contaminated.

(v) Break-point chlorination:

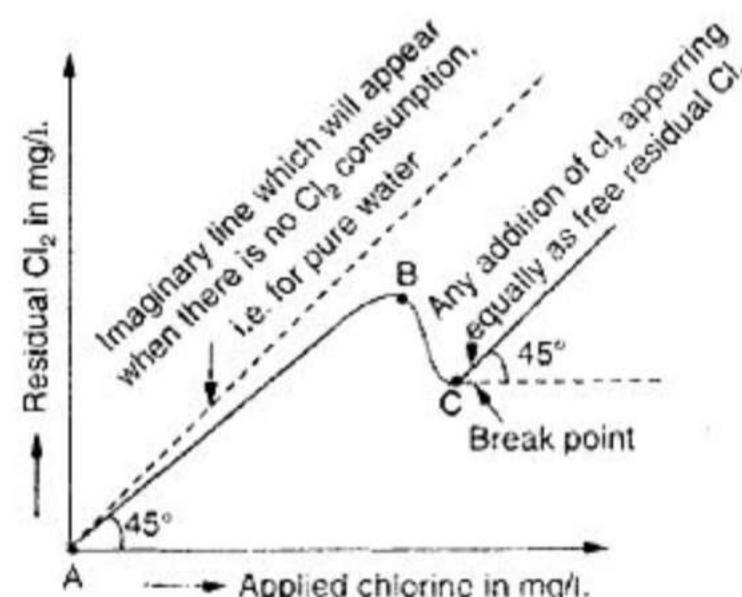


Fig:- Break point Chlorination

- Some Cl_2 is consumed for killing bacteria and thus the amount of residual Cl_2 shall be slightly less than that added as shown by the curve AB.
- If the addition of Cl_2 is continued beyond the point B, the organic matter present in water gets oxidised and therefore, the residual Cl_2 content suddenly falls down as shown by curve BC.
- Break point chlorination is a term which gives us an idea of the extent of chlorine added to water beyond which any further addition of chlorine will appear as free residual chlorine.
- The D.P.D. test will indicate the quantum of total residual chlorine "**combined**" as well as "**free**".
- The point C is the point beyond which any further addition of Cl_2 will appear equally as free chlorine. This point "C" is called the **break point**. The addition of Cl_2 beyond break point is called **break point chlorination**.
- It is a general practice to add Cl_2 beyond break point, and thus to ensure a residual of 0.2 to 0.3 mg/l of free chlorine.
- (vi) **Super chlorination:** It indicates the addition of excessive amount of chlorine (i.e., 5 to 15 mg/l) to the water. This may be required in some special cases of highly polluted water, or during epidemics of water borne diseases.
 - The huge quantity of Cl_2 is added in super chlorination is such as to give about 1 to 2 mg/l of residual beyond the break point in the treated water.
 - Sometimes, even higher doses may be used and the resultant water is dechlorinated after the end of the desired contact period, by using dechlorinating agent. This ensures the removal of bad tastes and odour caused by the presence of excess chlorine. Since residual Cl_2 is zero, so again chlorinate the water by a dose of about 0.1 to 0.2 mg/l.
- (vii) **Dechlorination:** It means removing of chlorine from water. The dechlorination may be carried out by adding certain chemicals to water or by **simple aerating the water**. These chemicals are called **dechlorinating agents**.

Some common dechlorinating agents are:

- (i) Sulphur dioxide gas (SO_2);

- (ii) Activated carbon;
- (iii) Sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$), cheapest dechlorinating agent
- (iv) Sodium metabisulphite ($\text{Na}_2\text{S}_2\text{O}_5$);
- (v) Sodium sulphite (Na_2SO_3);
- (vi) Sodium bisulphite (NaHSO_3); and
- (vii) Ammonia (NH_4OH).

Testing of chlorine residuals:

- (i) Orthotolidine test;
- (ii) D.P.D. test;
- (iii) Chlorotex test; and
- (iv) Starch iodine test.

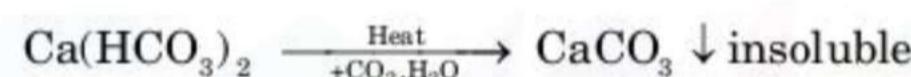
WATER SOFTENING

- The reduction or removal of hardness from water is known as water softening.

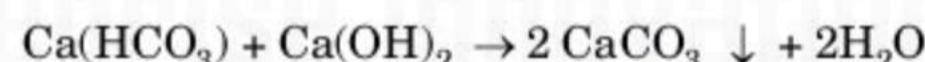
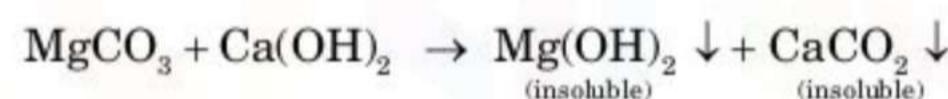
Methods of removing Temporary hardness:

Removed either by boiling or by adding lime to the water.

1. **Boiling:** When water is boiled, it leads to the precipitation of (CaCO_3) , which can be sedimented out in settling tank. But boiling cannot remove hardness caused by magnesium as MgCO_3 is fairly soluble in water



2. Addition of lime:



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

METHOD OF REMOVING PERMANENT HARDNESS

The three methods, which are commonly adopted for softening waters containing either permanent hardness or permanent as well as temporary hardness both, are

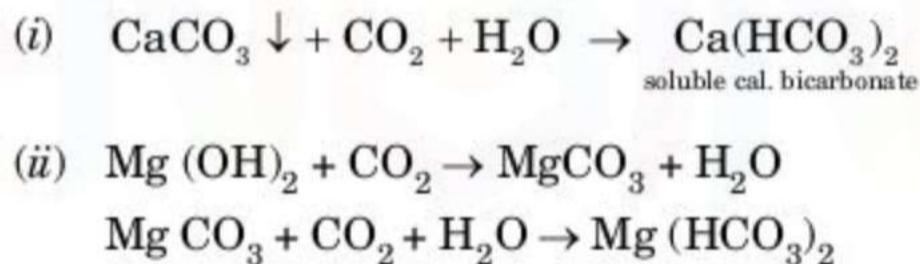
1. Lime soda process;
2. Base exchange process, generally called zeolite process; and
3. Demineralisation process.

1. Lime-Soda Process:

In this process lime $[Ca(OH)_2]$ and soda ash $[Na_2CO_3]$ are added to the hard water, which react with the Ca and Mg salts, to form insoluble precipitates of $CaCO_3$ and $Mg(OH)_2$. These precipitates can be sedimented out in sedimentation tank.

- (i) $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$
- (ii) (a) $Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow Ca(HCO_3)_2 + Mg(OH)_2 \downarrow$
(b) $MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3 \downarrow$
- (iii) $MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaCl_2$
- (iv) $MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaSO_4$
- (v) $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + H_2O$
(free dissolved CO_2)
- (vi) $CaCl_2 + Na_2CO_3$ (Soda) $\rightarrow CaCO_3 \downarrow + 2NaCl$
- (vii) $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + Na_2SO_4 \downarrow$

- After sedimentation of $CaCO_3$ and $Mg(OH)_2$, a little quantity may remain as finely divided particles and may cause trouble by getting deposited on the filter or in the pipes of the distribution system. To prevent this, water be recarbonated by passing CO_2 gas through it if leaves the sedimentation tank.



- Many of the hard water contain the carbonate hardness and very low amounts of non carbonate hardness.
- For treating all such waters, lime is often the only chemical required.
- The equipment required for lime soda treatment is similar to that required for chemical coagulation.
- The effluents from the recarbonation plant are finally passed through a rapid gravity filter.

Dry sludge produced in mg/l = $[Ca_R + 0.58 Mg_R + Li_A]$

where, Ca_R = Calcium hardness removed in mg/l.
(expressed as $CaCO_3$)

Mg_R = Magnesium hardness removed in mg/l. (expressed as $CaCO_3$)

Li_A = Lime added in mg/l. (expressed as $CaCO_3$)

ALKALINITY

It may be defined as the quantity of ions in water that will react to neutralise the hydrogen ion (H^+).

$$\text{Alkalinity} = [HCO_3^-] + [2CO_3^{--}] + [OH^-] - [H^+]$$

where, [] refers the concentration in moles/L.

- The carbonate hardness can be considered to be equal to the alkalinity provided, there is no sodium alkalinity in water.
- It follows that if non-carbonate hardness is present in water, then its carbonate hardness will be equal to its alkalinity, since sodium alkalinity will be zero.
- When $pH > 11.5$, the entire alkalinity is in the form of CO_3^{--} and OH^- .

When $7.5 < pH < 8.3$ the entire alkalinity is in the form of HCO_3^- .

When $pH < 4.5$ the entire alkalinity is in the form Carbonic acid H_2CO_3 .

Zeolite Process or Base-Exchange or Cation-Exchange process for Removing Hardness:

- General formula of Zeolites are $Na_x O Al_2 O_3 y SiO_2 y H_2O$. The usual value of x is 2 or more and that of y of ranging amounts.
- During softening operation, the sodium ions of the zeolite get replaced by the calcium and magnesium ions present in hard waters. The Co and Mg zeolite can be regenerated into active sodium zeolite by titrating it with 5–10% solution of sodium chloride.
- Zeolite softeners may be either gravity or pressure filters; pressure filter type zeolite softeners being more common. The rate of filtration through a zeolite softener is about 300 l/minute/m² i.e. 18000 l/h./m².
- The zeolite process will result in a water of zero hardness, which generally is not suitable for public supplies. Therefore, only a portion of the water passing through the treatment plant is to be soften and then mixed with unsoftened water to obtain the desired water quality.

Comparison of Lime-Soda and Zeolite Processes of softening water supplies.

S.No.	Item	Lime Soda Process	Zeolite Process
1.	Size of plant	Bulky and Large	Compact and small.
2.	Skilled super-vision if required.	Careful and skilled supervision is necessary for obtaining results.	Automatic and easy to operate.
3.	Sludge troubles, if any	Large quantity of sludge is formed.	No sludge is formed.
4.	Post treatment if needed.	Recarbonation is a must after sedimentation and filtration.	No such post treatment is required.
5.	Results obtained	It can produce water of hardness not less than about 50 mg/l. Therefore, useful for public supplies only.	Water of zero hardness can be obtained.
6.	Removal of colour due to iron and manganese.	Can remove the colour due to iron and manganese, but only to a very small extent.	Can remove the colour due to Fe & Mn, although very costly for treating such waters, because the exhausted Mn and Fe zeolite cannot be regenerated.
7.	Effects on bacteria	The increased causticity may help in killing pathogenic bacteria.	No such advantage is offered by this process.
8.	pH of the treated water	Increases the pH value of water, which reduces the corrosion of distribution pipes.	pH value of the water is not affected.
9.	Economy	Process is economical and can be easily combined with usual water treatment methods at slight extra cost.	Process is costlier.
10.	Hardness which can be treated	Excessively hard waters can be treated.	Raw waters with hardness greater than 800 mg/l. cannot be easily and economically treated.
11.	Allowable turbidity in raw waters.	Highly turbid and acidic water can be treated.	Highly turbid waters are difficult to be treated.

Demineralisation Process for Removing Hardness:

- It means removing the minerals from the water. This demineralised water, sometimes called *de-ionised water*, is as pure as distilled water, and is very suitable for industrial purposes.
- This complete removal of minerals present in water can be carried out by first passing the water through a bed of cation exchange resins, and then through a bed of anion exchange resins.

MISCELLANEOUS TREATMENTS

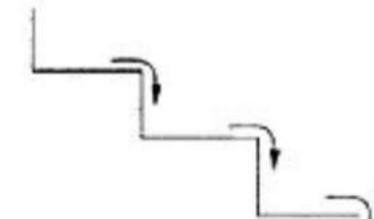
The fluoride content of the water should neither be less as to cause dental caries (early tooth decay) in children, during the calcination of their permanent teeth, nor it should be too high as to cause fluorosis (discolouration of teeth) and even deformation of bones (in extreme cases).

REMOVAL OF COLOURS, ODOURS AND TASTES FROM WATER

1. **Aeration:** Under the process of aeration, water is brought in intimate contact with air, so as to absorb oxygen and to remove CO_2 gas. It may also help in killing bacteria, removing H_2S gas, 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 :

- (i) By using spray nozzles
- (ii) By permitting water to trickle over cascades;
- (iii) By air diffusion;
- (iv) By using trickling beds:
More efficient than cascades.



2. Treatment with activated carbon: It possesses the property of absorbing and attracting impurities, such as gases, liquids and finely divided solids. It is widely used for removing tastes and odours from public supplies. It is very useful for removing phenol type impurities.

- The activated carbon is available under various potential trade names, such as **Darco**, Nuchar etc. It is available in granular as well as powder forms.
- The activated carbon is mostly used in the powdered form and may be added to the water either before or after the coagulation, but before filtration.
- Activated carbon may also be used in the granular form as a filter media.

Advantage of activated carbon:

- (i) It reduces the chlorine demand of treated water.
- (ii) It removes the organic matter present in water.
- (iii) It removes the tastes, odours and colours caused by the presence of Fe, Mn, phenols, excess chlorine, H_2S etc.
- (iv) Its overdose is not harmful.

3. Treatment with copper sulphate ($CuSO_4 \cdot 7H_2O$): Algae control compound.

The solution of $CuSO_4$ may be prepared and added just at the entry of water into the distribution system.

4. Treatment with oxidising agents:

The oxidising agents commonly used are $KMnO_4$, Cl_2 , O_3 etc.

REMOVAL OF IRON AND MAGANESE FROM WATER

- When present without combination with organic matter, they can be easily removed by aeration. On the other hand, when iron and manganese are present in combination with organic matter, it becomes difficult to break the bond between them and removal.
- Manganese can be removed by activated alumina.

FLUORIDATION AND DEFLOURIDATION OF WATER

- The process of adding fluoride compounds is called **fluoridation**.

Compounds used are:

Sodium fluoride (NaF) (mostly used), sodium silica fluoride (Na_2SiF_6), hydrofluosilic acid (H_2SiF_6) etc.

- The process of removal of fluorine is called **defluoridation** process. Process used are:

Lime soda process, cation exchange etc.

- Fluorides are removed by manganese zeolite.

REMOVAL OF RADIOACTIVITY FROM WATER

Certain promising methods which are studied for removing radioactivity from water are:

- (i) By phosphate coagulation method;
- (ii) By electrolysis method;
- (iii) By adding of clay materials to water; and
- (iv) By adding of metallic dusts of water.

DESALINATION OF BRACKISH WATER

The process of removing salts such as $NaCl$ from water is known as **desalination**.

- Scarcity of water – Hongkong (import from other country)
- Desalination is a very costly process.
- National Chemical Laboratory (Poona), and Central Arid zones Research Institute (Jodhpur) are busy on this subject.

Methods of desalination:

Various methods which are generally adopted for the conversion of salt water into fresh waters are:

- (i) Desalination by evaporation and distillation;
- (ii) Electrodialysis method;
- (iii) Reverse osmosis method;
- (iv) Freezing process;
- (v) Solar distillation method; and
- (vi) Other methods.

DISTRIBUTION SYSTEM

The distribution pipe system consists of supply **mains**, **submains**, **branches** and laterals.

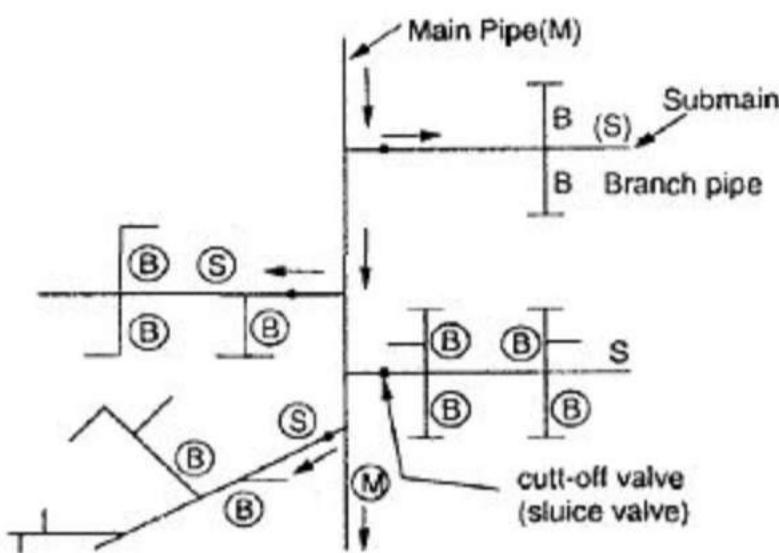
AYOUTS OF DISTRIBUTION NETWORK

In general, four different types of pipe network; any one of which either singly or in combinations, can be used for a particular place.

1. Dead-end system or Tree system;
2. Grid iron system or Interlaced system or Recirculation system;
3. Ring system or circular system; and
4. Radial system.

1. Dead-end system:

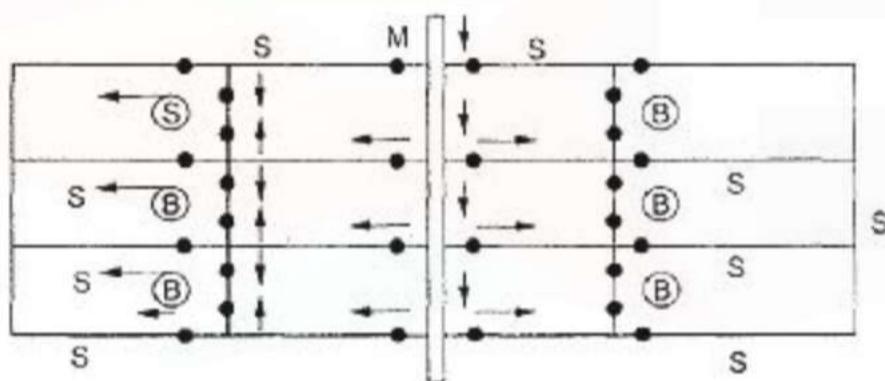
This type of layout may have to be adopted for older towns which have developed in a haphazard manner. So formation of number of dead-ends.



This system is suitable for countries which expand irregularly.

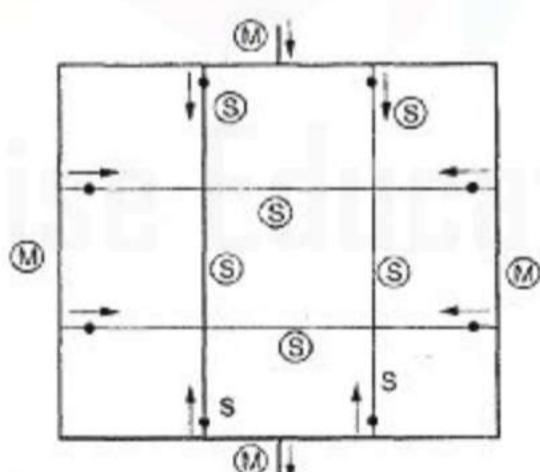
- **Dead-end:** The termination or end point of the pipe is known as a **dead-end**.
- Economy and simplicity.

2. Grid-iron system:



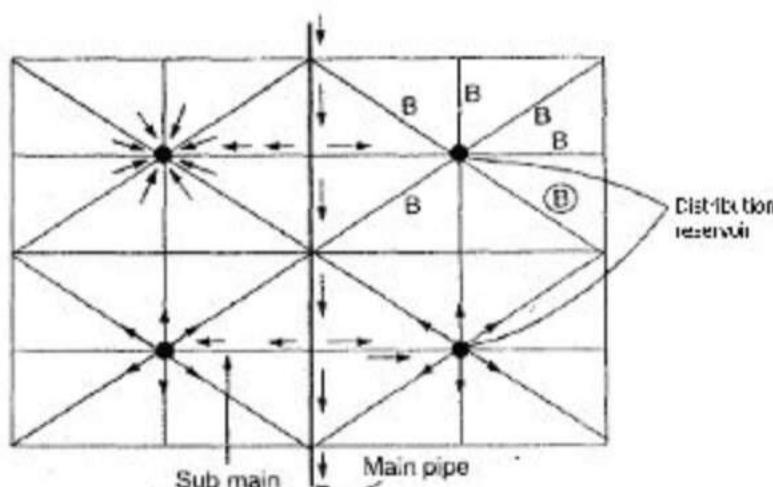
- Suitable for well planned towns and cities.
- Require larger number of sluice valves.
- Both economy and reasonably equal pressures.

3. Ring system:



- Equal pressure and multiple flow paths.

4. Radial system:



- Zonal distribution

METHODS OF DISTRIBUTION

The water may be forced into the distribution system in the following three ways:

1. By gravitational system;
2. By pumping system or Pumping without storage system;
3. By combined gravity and pumping system called Pumping with storage system. (Adopted these days).

PRESSURE IN THE DISTRIBUTION SYSTEM

- The greater the design pressure, the costlier it will be, but will cause more convenience to the consumers.

Sluice value or cut-off value: To control flow of water through pipe lines.

Air valve: To release the accumulated air in pipe.

Score valve: To remove silt in a pipe line.

Check valve: To prevent entry of pollution into the pure water.

DISTRIBUTION RESERVOIR OR SERVICE RESERVOIR

Type of distribution reservoirs:

- | | |
|-------------------------------------------|---------------------------------------|
| 1. Surface reservoir or ground reservoir. | } Made of R.C.C,
steel or masonry. |
| 2. Elevated reservoir. | |

STAND PIPES

Stand pipes are a kind of elevated tanks without any erected towers for resting the tank body. They are thus tall cylindrical shells resting directly on the ground, acts like elevated reservoir.

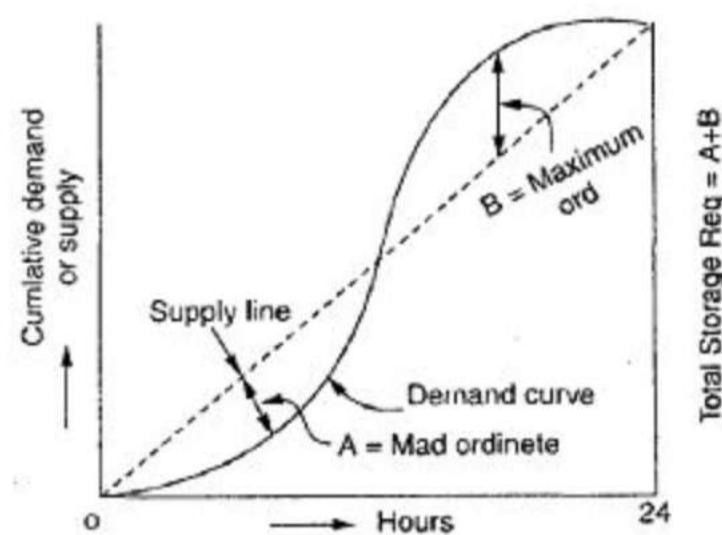
STORAGE CAPACITY OF DISTRIBUTION RESERVOIRS

The total storage capacity of a distribution reservoir is the summation of:

1. Balancing storage (or equalising or operating storage);
2. Breakdown storage; and
3. Fire storage.

Balancing storage or Equalising storage: The main and primary function of a distribution reservoir is to meet the fluctuating demand with a constant rate of supply from the treatment plant. The quality of water required to be stored in the reservoir for equalising or balancing this variable demand against the constant supply is known as the balancing reservoir or balancing storage or the storage capacity of a balancing reservoir.

- This balancing storage can be worked out by **mass curve method** or by using an **analytical solution**.

Mass curve method:**QUALITY OF SEWAGE**

Characteristics and Quality of sewage must be determined before its disposal because of following :

- Floating solids of untreated sewage decompose and create unpleasant smells and odour in the river water.
- Large amount of organic matter present in untreated sewage starts consuming dissolved oxygen of the river water. Due to less amount of dissolved oxygen in river water, fish start dying.
- Untreated sewage is also responsible for contaminating source water with harmful micro-organisms called *pathogenic bacteria*. Pathogens are responsible for causing serious water borne diseases such as cholera, typhoid, dysentery, etc.

Though municipal sewage normally contains 99.9% of water content, it is always desirable to treat the sewage before discharging the same in the river water to safe guard against the above defects.

Factors deciding Extent and Type of treatment required for the Sewage so as not to pollute Source of disposal :

- Character and quality of sewage
- Source of disposal

Treatment of Sewage

Out of millions bacteria generally found per litre of untreated sewage, only a small number are harmful to man. These harmful bacteria are called *pathogens*. The remaining large number of bacteria called *non-pathogens* are not only harmless but useful for the process of decomposition of the sewage. The main basis of treatment of sewage is to provide a suitable environment for the action of aerobic and anaerobic bacteria for stabilising organic matter present in sewage either through aerobic or anaerobic decomposition.

Decomposition of Sewage

- Aerobic decomposition.** During treatment, in aeration tanks, contact beds, intermittent sand filters, trickling filters and oxidation ponds, it is primarily done by oxidation.

- Anaerobic decomposition.** During treatment, in septic tanks, Imhoff tanks and sludge digestion tanks, it is mainly done by putrefaction alone.

CHARACTERISTICS OF SEWAGE**I. Physical Characteristics**

- Turbidity.** Degree of turbidity of sewage may be measured either by a turbidity rod or turbid meter. The degree of turbidity increases with the increase of sewage strength.
- Colour.** Colour of sewage indicates degree of its freshness. Black or dark brown colours indicate stale and septic sewage.
- Odour.** Fresh sewage remains practically odourless. As soon as dissolved oxygen gets exhausted, the sewage first becomes septic and thereafter offensive odours are evolved due to decomposition of sewage. Hydrogen sulfide gas is generally liberated from stale decomposed sewage.
- Temperature.** Temperature of untreated sewage affects following
 - Biological activities of the bacteria present in the sewage.
 - Solubility of gases in the sewage.
 - Viscosity of sewage which ultimately affects the sedimentation process.
- Solids.** It contain 99.9% water and 0.1% solids.

II. Chemical Characteristics**1. Total Solids**

Solids may exist in the sewage in any of the following forms :

- Suspended solids :** These solids remain floating in sewage.
- Dissolved solids :** These solids remain dissolved in sewage.
- Colloidal solids :** These are finely divided solids which remain either in solution or in suspension.
- Settleable solids :** These are solid matter which settles at the bottom of the container in case sewage-is kept undisturbed for a period of two hours.

Proportion of different types of Solids per 1000 kg of sewage

Total solids	0.45 kg.
Suspended solids	0.112 kg.
Dissolved solids	0.225kg.
Settleable solids	0.112 kg